DIMENSIONAL CHANGES IN AERIAL PHOTOGRAPHIC FILMS AND PAPERS

BY RAYMOND DAVIS AND EMORY J. STOVALL
BUREAU OF STANDARDS

RESULTS OF A STUDY OF DIMENSIONAL CHANGES IN AERO MAPPING PHOTOGRAPHIC FILM AND PAPERS UNDER CONTROLLED CONDITIONS ARE PRESENTED. BOTH FILMS AND PAPERS ARE SUBJECT TO A SHRINKAGE FROM PROCESSING. THESE MATERIALS ARE HYGROSCOPIC, CONSEQUENTLY THEIR DIMENSIONS CHANGE WITH THE MOISTURE CONTENT OF THE AIR. DIMENSIONAL CHANGES FROM BOTH PROCESSING AND MOISTURE CONTENT ARE LEAST IN THE MACHINE DIRECTION; THAT IS, ALONG THE ROLL. FILMS CONTINUE TO SHRINK WITH TIME, BECAUSE OF A LOSS OF SOLVENTS AND PLASTICIZER. THIS SHRINKAGE IS ILLUSTRATED BY ACCELERATED AGING TESTS AT 120°F COVERING A PERIOD OF 32 DAYS. TWO NEW INSTRUMENTS FOR MEASURING FILM SHRINKAGE WHICH WERE DEVELOPED FOR THIS WORK ARE DESCRIBED. A REDUCTION OF DIFFERENTIAL SHRINKAGE IN THE FINAL PRINT OR DUPLICATE NEGATIVE CAN BE HAD BY CROSSING THE MACHINE DIRECTIONS OF THE NEGATIVE AND PRINTING MATERIAL DURING EXPOSURE.

INTRODUCTION

PHOTOGRAPHIC FILMS AND PAPERS ARE NOT STABLE WITH REGARD TO THEIR DIMENSIONAL CHARACTERISTICS. IT IS WELL KNOWN THAT THESE MATERIALS NOT ONLY CHANGE THEIR DIMENSIONS WITH A CHANGE IN MOISTURE CONTENT WHICH TENDS TO FOLLOW SIMILAR CHANGES IN THE ATMOSPHERE, BUT ARE SUBJECT TO SHRINKAGE CAUSED BY THE PROCESS OF DEVELOPING, FIXING, AND WASHING. FOR AERIAL SURVEYING USE, THE DIMENSIONAL CHANGE IS NOT SERIOUS IF UNIFORM IN ALL DIRECTIONS AND ITS MAGNITUDE KNOWN, AS A CHANGE OF SCALE IS ALL THAT WOULD BE NEEDED FOR CORRECTION. THE ACTUAL CASE IS COMPLICATED BY THE FACT THAT BOTH PAPERS AND FILMS SHRINK MORE IN ONE DIRECTION THAN IN THE OTHER. BOTH PAPER AND CELLULOID ARE MANUFACTURED BY CONTINUOUS PROCESS, THE PRODUCT BEING IN THE FORM OF A LONG RIBBON. THE GREATEST SHRINKAGE IS ALWAYS IN THE CROSSWISE DIRECTION.

WHILE THESE FACTS HAVE BEEN KNOWN FOR A LONG TIME, ONLY MEAGER AND INCOMPLETE DATA ON THE MAGNITUDE OF THE EFFECTS OF MOISTURE AND PROCESSING UNDER CONTROLLED CONDITIONS HAVE BEEN AVAILABLE. DURING THE LAST FEW YEARS, AERIAL SURVEYING HAS BEEN UNDERTAKEN ON A LARGE SCALE AND THE NEED FOR INFORMATION ON THE DIMENSIONAL CHANGES IN FILMS AND PAPERS HAS BECOME ACUTE, AND FOR WORK WHERE HIGH ACCURACY IS DESIRED CONSIDERABLE DIFFICULTY HAS BEEN ENCOUNTERED IN OBTAINING THESE MATERIALS WITH SATISFACTORY SHRINKAGE CHARACTERISTICS. THE BETTER AERIAL CAMERAS ARE FITTED WITH LENSES WHICH HAVE BEEN SELECTED WITH A MINIMUM OF DISTORTION. THE MAGNITUDE OF DISTORTION FOR THESE LENSES IS OF THE ORDER OF 0.04 MM AT THE EDGE OF A 22.9 x 22.9 CM (9" x 9") PLATE. THIS VALUE AMOUNTS TO 0.035%. IN FILMS THE DISTORTION IS MEASURED BY THE DIFFERENCE IN SHRINKAGE EXPRESSED IN PERCENT IN THE TWO DIRECTIONS AND IS CALLED "DIFFERENTIAL SHRINKAGE." THE DIFFERENTIAL SHRINKAGE IN FILMS SHOULD NOT EXCEED THE DISTORTION OF THE LENSES, THAT IS, 0.035%.

MATERIALS

THE AMERICAN SOCIETY OF PHOTOGRAMMETRY THROUGH ITS PRESIDENT, COLONEL H. H. BLEE, UNDERTOOK THE TASK OF SECURING FILM AND PAPER SAMPLES FROM PHOTOGRAPHIC MANUFACTURERS, GOVERNMENTAL AGENCIES AND PRIVATELY OPERATED AERIAL SURVEYING SERVICES. THE FILM AND PAPER SAMPLES TESTED ARE REPRESENTATIVE OF THOSE IN CURRENT USE FOR AERIAL MAPPING WITH THE EXCEPTION OF TWO SAMPLES OF CUT FILM, ONE OF WHICH WAS EXPERIMENTAL. FROM TWO TO EIGHT SAMPLES OF EACH BRAND OF FILM WERE TESTED, EACH SAMPLE BEING FROM A DIFFERENT LOT OF THE SAME TRADE NAME. THE DIFFERENT SAMPLES OF THE SAME BRAND ARE GROUPED TOGETHER IN THE TABLES. FROM THESE GROUPS AN IDEA CAN BE HAD OF THE UNIFORMITY OF THE PRODUCT. IN ALL, 24 SEPARATE LOTS OF FILM WERE TESTED AND WITH THE EXCEPTION OF TWO SAMPLES ALL WERE ON A NITRATE BASE.

MOST OF THE PAPERS SUBMITTED WERE REGULAR PHOTOGRAPHIC PAPERS. IN ALL THERE WERE 57 ITEMS OF WHICH ONLY EIGHT WERE MARKED SPECIAL LOW SHRINK OR AERO MAPPING PAPERS.

APPARATUS AND METHODS OF MEASURING SHRINKAGE

APPARATUS SUITABLE FOR MEASURING FILM SHRINKAGE MAY BE OF TWO GENERAL

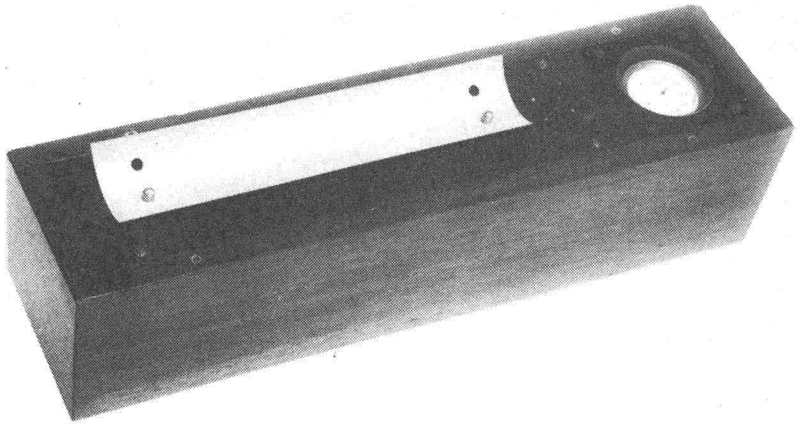


Figure 1
Pin gage, with strip of film in place for measurement

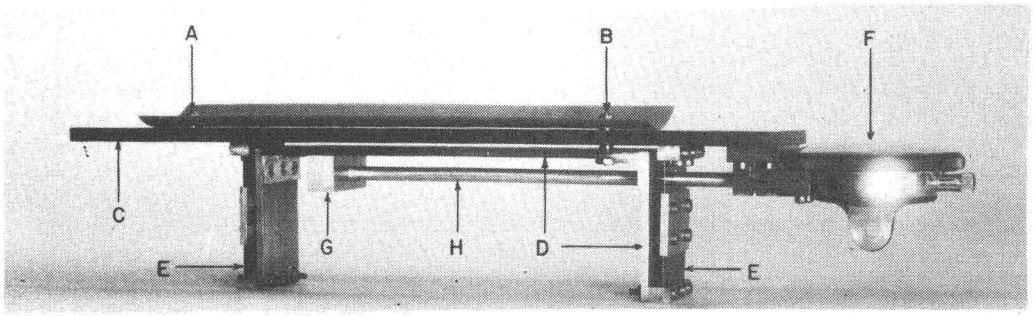


Figure 2
Pin gage removed from its case

A - Fixed pin
B - Movable pin
C - Face plate
D - suspension bridge
E - Flexure plate
F - Dial gage
G - Anchor block for H
H - Duralúminum rod for temperature compensation

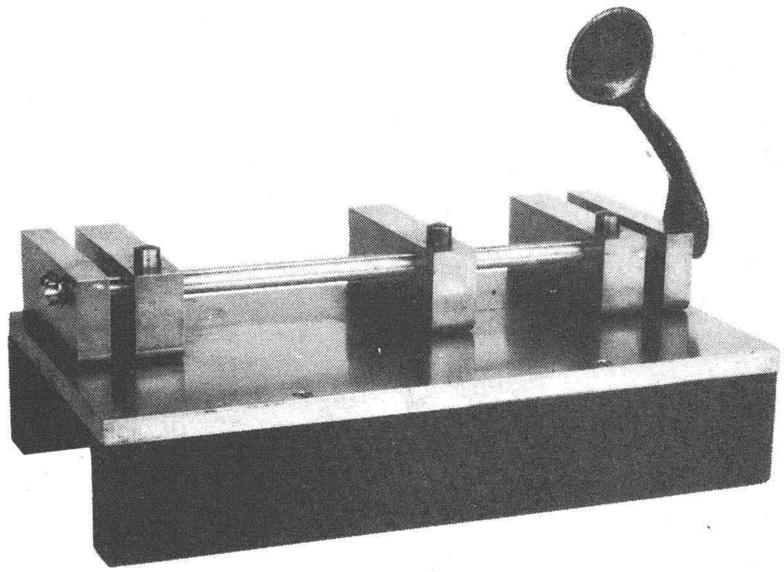


Figure 3
Punch used for making reference holes in films, either 5 inches or 8 inches apart

TYPES, EITHER OPTICAL OR MECHANICAL. THE OPTICAL DEVICES GENERALLY USED CONSIST OF EITHER A MICROMETER MICROSCOPE ACTUATED BY A CALIBRATED SCREW SUCH AS FOR MEASURING LINE SPECTRUM NEGATIVES, OR THE COMPARATOR TYPE OF INSTRUMENT WITH WHICH A LENGTH STANDARD IS COMPARED BY TWO MICROMETER MICROSCOPES WITH REFERENCE MARKS ON THE FILM.

THE USE OF DEVICES EMPLOYING MICROSCOPES IS BOTH SLOW AND LABORIOUS, AN IMPORTANT DRAWBACK IN A LARGE NUMBER OF MEASUREMENTS. RAPID AND CONVENIENT MEANS OF MEASURING FILM SHRINKAGE NOT BEING AVAILABLE, TWO DIFFERENT INSTRUMENTS WERE DESIGNED AND CONSTRUCTED FOR THIS WORK, ONE A MECHANICAL GAGE OR EXTENSOMETER FOR FILMS WHICH IS BOTH RAPID AND ACCURATE, AND THE OTHER AN OPTICAL EXTENSOMETER SUITABLE FOR BOTH PAPER AND FILMS.

THE USE OF THIS MECHANICAL EXTENSOMETER, REFERRED TO THROUGHOUT THIS REPORT AS "PIN GAGE", DOES NOT NECESSITATE THE USE OF A DARKROOM SINCE NO DEVELOPED IMAGE IS USED IN THE MEASUREMENTS.

THE PROCEDURE WITH THE PIN GAGE IS AS FOLLOWS: STRIPS TWO INCHES WIDE AND 10 INCHES LONG ARE CUT FROM THE FILM FOR LENGTHWISE SAMPLES. CROSSWISE SAMPLES ARE CUT THE SAME WIDTH BUT ARE 9-1/2 INCHES LONG, THIS LATTER BEING THE FULL WIDTH OF 24-CENTIMETER AERIAL FILM. THE DIFFERENCE IN LENGTH SERVES TO DISTINGUISH THE LENGTHWISE SAMPLES FROM THE CROSSWISE. HOWEVER, EACH INDIVIDUAL TEST STRIP IS ALSO GIVEN AN IDENTIFYING NUMBER. AFTER CUTTING, WHICH IS DONE IN A LIGHTED ROOM, THE FILM SAMPLES ARE NUMBERED AND HUNG UP WITH WOODEN PHOTO CLIPS IN THE CONDITIONING ROOM FOR THE PRESCRIBED TIME. AT THE EXPIRATION OF THE CONDITIONING PERIOD THE FILMS ARE PUNCHED WITH TWO PAIRS OF HOLES 1/4 INCH IN DIAMETER AND EIGHT INCHES APART AS ILLUSTRATED IN FIGURE 1, OR FIVE INCHES APART FOR USE WITH A 5-INCH GAGE IN THE CASE OF NARROW FILM.

THE PUNCHED FILM IS MEASURED ON THE PIN GAGE AND THE READINGS RECORDED. THE SAMPLES ARE THEN DEVELOPED, FIXED, WASHED AND DRIED, AND RETURNED TO THE CONDITIONING ROOM. AFTER RECONDITIONING FOR THE PRESCRIBED TIME, THEY ARE AGAIN MEASURED WITH THE PIN GAGE. THE DIFFERENCE BETWEEN THE PIN GAGE READINGS BEFORE AND AFTER DEVELOPING GIVES THE DIMENSIONAL CHANGE DUE TO PROCESSING.

THE 8-INCH PIN GAGE, REMOVED FROM ITS CASE, IS ILLUSTRATED IN FIGURE 2. IN THIS, A AND B ARE STEEL PINS 1/4 INCH IN DIAMETER WITH ROUNDED ENDS. PIN A IS FIXED TO THE HEAVY STEEL FACE PLATE C AT A DISTANCE OF 7-3/4 INCHES FROM PIN B, OUTSIDE MEASURE BEING EIGHT INCHES. PIN B PASSES THROUGH A SLOT IN THE FACE PLATE AND IS FASTENED TO A SUSPENSION BRIDGE D IMMEDIATELY BELOW. THE BRIDGE SUPPORTING THIS MOVABLE PIN B IS SUSPENDED FROM THE UNDERSIDE OF THE FACE PLATE BY TWO SPRING STEEL FLEXURE PLATES E AND E', 0.005 INCHES THICK, ONE AT EACH END, WHICH PERMITS THE BRIDGE SUPPORTING THE MOVABLE PIN TO MOVE TOWARD AND AWAY FROM THE FIXED PIN, A TOTAL DISTANCE OF APPROXIMATELY 1/10 INCH. A DIAL GAGE F FASTENED TO THE UNDERSIDE OF THE FACE PLATE IS CONNECTED TO THE SUSPENSION BRIDGE AT THE POINT G BY A METAL ROD H. THE FACE PLATE AND BRIDGE IS MADE OF STEEL AND THE ROD H IS DURALUMINUM OF SUCH A LENGTH THAT IT COMPENSATES FOR CHANGES OF TEMPERATURE. FOR THE WORK REPORTED HERE, TEMPERATURE COMPENSATION WAS UNNECESSARY; BUT THE CORRECTION WAS SO SIMPLE TO MAKE THAT THIS FEATURE WAS INCORPORATED IN THE DESIGN. A COIL SPRING (NOT SHOWN IN FIGURE 2) FASTENED TO THE FACE PLATE AND SUSPENSION BRIDGE MAINTAINS TENSION OF ABOUT 75 GRAMS ON THE SAMPLE PLACED OVER THE PINS. THE HOLES IN THE FILM WERE MADE WITH A PUNCH (FIGURE 3) DESIGNED FOR THE PURPOSE. THE LEVER BAR AND PUNCH PIN WERE FROM A HUMMER PAPER PUNCH. THE PUNCH WAS MACHINED TO SPECIFIED DIMENSIONS, AND HARDENED STEEL DIES MADE TO FIT WERE IMBEDDED IN THE STEEL BASE PLATE. THIS PUNCH MAKES CLEAN HOLES FOR EITHER 5-INCH OR 8-INCH GAGE LENGTHS. A METAL PLATE (NOT SHOWN) MAY BE USED TO KEEP THE FILM FLAT DURING THE PUNCHING OPERATION. SINCE THE FILM IS MEASURED AFTER PUNCHING AND BEFORE PROCESSING, HIGH ACCURACY IN THE SPACING OF THE HOLES IS UNNECESSARY; HOWEVER, IF CARE IS TAKEN, EXCELLENT REPRODUCIBILITY CAN BE OBTAINED.

ORDINARILY 30 TEST STRIPS WERE CUT FROM EACH ROLL OF AERO FILM TESTED, 15 CUT CROSSWISE AND 15 LENGTHWISE. ONE GROUP OF STRIPS, FIVE IN EACH DIRECTION, WAS LEFT UNPROCESSED IN THE CONDITIONING ROOM AS A CONTROL. THE PROCESSED SAMPLES WERE FIRST CONDITIONED AS MENTIONED, DEVELOPED IN TRAYS FOR 3

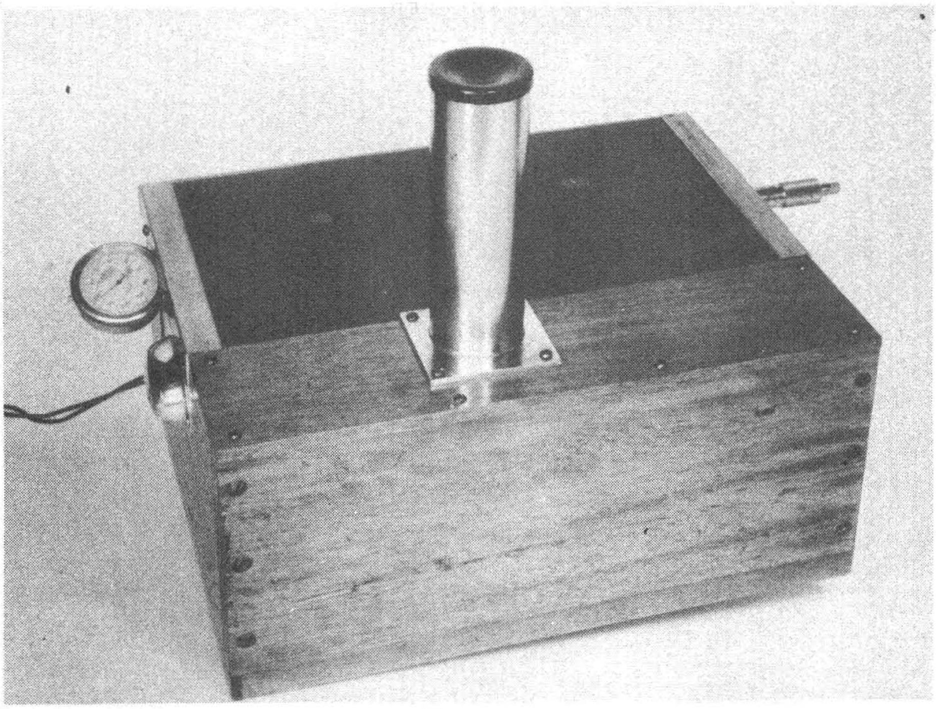
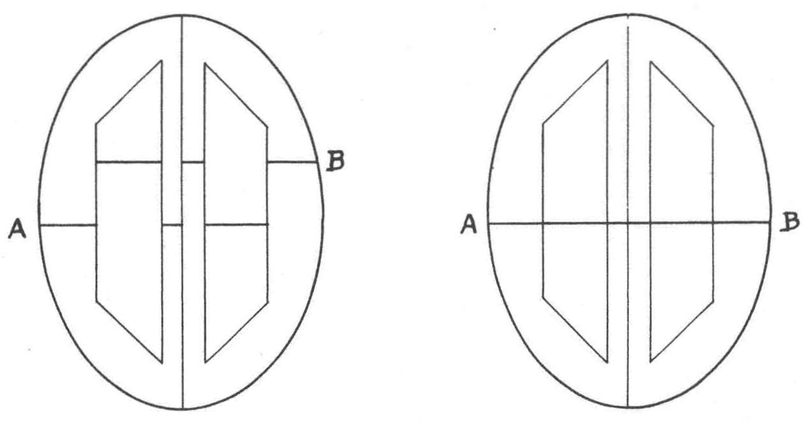


Figure 4
The optical gage



Figures 5 and 6
Patterns observed in the eyepiece of the optical gage
(A is imaged by the fixed objective, B by the movable one)

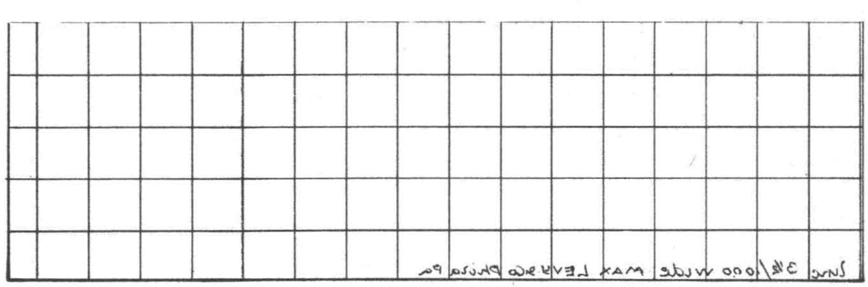


Figure 7
Portion of a print from a negative of the ruled glass grid

MINUTES IN A METOL-HYDROQUINONE DEVELOPER, RINSED IN A DILUTE ACETIC ACID SHORT STOP BATH, FIXED 12 TO 15 MINUTES IN AN ACID HARDENING FIXING BATH, WASHED 30 MINUTES TO AN HOUR IN RUNNING WATER, AND HUNG UP TO DRY IN THE UNCONTROLLED ATMOSPHERE OF THE LABORATORY. WHEN DRY THEY WERE RETURNED TO THE CONDITIONING ROOM, CONDITIONED FOR THE PRESCRIBED TIME AND REMEASURED ALONG WITH THE CONTROL STRIPS, TO DETERMINE THE SHRINKAGE DUE TO PROCESSING. A THIRD GROUP OF FILM STRIPS, CUT, PUNCHED, PROCESSED AND MEASURED AS BEFORE WERE PLACED IN A PAPER ENVELOPE (TO PREVENT EXCESSIVE CURLING) IN AN OVEN MAINTAINED AT 120°F (49°C), USUALLY FOR SEVEN DAYS, THEN TAKEN BACK INTO THE CONDITIONING ROOM, RECONDITIONED AND MEASURED.

EXCELLENT RESULTS ON FILM WERE OBTAINED WITH THE PIN GAGE, BUT WITH PHOTOGRAPHIC PAPERS THIS PROCEDURE WAS NOT SATISFACTORY. PAPER IS NOT SUFFICIENTLY FLEXIBLE NOR DOES IT HAVE THE MECHANICAL STRENGTH OR WEAR RESISTANCE TO GIVE GOOD REPRODUCIBILITY. USING THE MECHANICAL PRINCIPLES OF THE PIN GAGE AN OPTICAL EXTENSOMETER WAS DESIGNED FOR MEASURING PAPER SHRINKAGE. THIS INSTRUMENT IS SHOWN IN FIGURE 4. THE BOX CONTAINS A MECHANISM SIMILAR TO THE PIN GAGE EXCEPT THAT THE TWO PINS ARE REPLACED WITH TWO 32 MM MICRO-TESSAR OBJECTIVES, ONE MOVABLE AND THE OTHER FIXED. THESE LENSES ARE IN FIXED FOCUS ON THE UPPER SURFACE OF THE PLATE GLASS TOP OF THE INSTRUMENT. THE GLASS IS PAINTED BLACK ON THE UNDERSIDE EXCEPT FOR TWO RECTANGULAR PATCHES IMMEDIATELY ABOVE THE OBJECTIVES. BY MEANS OF PRISMS THE BEAMS FROM THE LENSES ARE BROUGHT TO A FOCUS ON A LUMMER BRODHUN PHOTOMETRIC CUBE WHICH BRINGS THE SEPARATE IMAGES INTO JUXTAPOSITION. A BRASS TUBE FITTED WITH A LENS AND HARD RUBBER CAP WITH A SMALL HOLE, CONSTITUTES THE EYEPIECE OF THE INSTRUMENT. THIS IS FOCUSSED ON THE PHOTOMETRIC CUBE. ON THE END OF THE BOX TO THE RIGHT A MICROMETER IS FITTED TO MOVE AND MEASURE THE LENS DISPLACEMENT AND ON THE OTHER END OF THE BOX IS A DIAL GAGE, WHICH ALSO INDICATES THE POSITION OF THE LENS. EITHER MICROMETER OR DIAL GAGE MAY BE READ; HOWEVER, THD DIAL GAGE, WHILE SLIGHTLY LESS ACCURATE THAN THE MICROMETER IS PREFERABLE BECAUSE OF EASE OF READING. THE GAGE LENGTH OF THIS INSTRUMENT (DISTANCE BETWEEN LENSES) IS SIX INCHES. TO ILLUSTRATE THE OPERATION OF THE INSTRUMENT: IF A PRINT ON PAPER OR FILM HAVING A PAIR OF PARALLEL LINES SPACED SIX INCHES APART BE PLACED FACE DOWN ON THE GLASS TOP OF THE INSTRUMENT SO THAT THE LINES ARE IN THE FIELD OF VIEW OF THE LENSES ONE MIGHT SEE IN THE EYEPIECE A PATTERN SUCH AS IS SHOWN IN FIGURE 5. IN THIS FIGURE, LINE A IS PRODUCED BY THE FIXED LENS AND LINE B IS FROM THE MOVABLE LENS. IF THE MICROMETER SCREW IS TURNED IN THE PROPER DIRECTION LINE B WILL BE MOVED INTO COINCIDENCE WITH LINE A AS SHOWN IN FIGURE 6. THE MAGNIFICATION HERE IS 10 DIAMETERS. THE OBVIOUS ADVANTAGE OF THIS INSTRUMENT, WHERE BOTH FIELDS ARE SEEN IN A SINGLE EYEPIECE, OVER THE USUAL COMPARATORS IS THAT A SINGLE SETTING IS SUFFICIENT. COMPARATORS ORDINARILY REQUIRE SEPARATE SETTINGS ON THE TWO REFERENCE LINES. MATCHING ENDS OF LINES AS IN THE PRESENT INSTRUMENT, SEEMS MORE ACCURATE THAN CENTERING A LINE BETWEEN TWO PARALLEL HAIRS OR, CENTERING ON CROSS-HAIRS IN TWO OBSERVING MICROSCOPES FOR A SINGLE MEASUREMENT.

TO DETERMINE THE SHRINKAGE OF PHOTOGRAPHIC PAPER OR FILM WITH THIS OPTICAL GAGE, THE SAMPLE AFTER CONDITIONING IN THE DARK IS EXPOSED IN THE CONDITIONING ROOM UNDER A NEGATIVE OF A MAX LEVY RULED GLASS GRID CONSISTING OF FINE LINES SPACED 1/2 INCH, AS SHOWN IN FIGURE 7. AFTER DEVELOPING, FIXING, WASHING, AND DRYING, THE SAMPLE IS RECONDITIONED FOR A PRESCRIBED INTERVAL OF TIME AND THEN MEASURED. IN THE MEASURING OPERATION, THE FIRST STEP IS TO MEASURE A SIMILAR REFERENCE PRINT OF THIS GRID MADE ON A PHOTOGRAPHIC PLATE, IN SIX DIFFERENT POSITIONS, THREE LENGTHWISE AND THREE CROSSWISE. WITH THE FIXED DIMENSIONS OF THE PLATE AS STANDARD THE SEPARATION OF SIX PAIRS OF POINTS ON THE SAMPLE ARE COMPARED WITH THAT OF THE SAME PAIRS OF POINTS ON THE GRID. AFTER MEASUREMENT OF THE PAPER OR THE FILM HAS BEEN COMPLETED THE STANDARD PLATE IS AGAIN MEASURED TO CHECK THE ZERO OF THE INSTRUMENT.

REPRODUCIBILITY OF THE MEASUREMENTS

TO OBTAIN ACCURATE READINGS WITH THE PIN GAGE AND TO AVOID DAMAGE TO THE FILM CAREFUL HANDLING IS NECESSARY. THE MANNER OF PLACING THE FILM ON THE POINTS AND REMOVING IT IS IMPORTANT. THE STRIP SHOULD BE GRASPED BY THE ENDS BETWEEN FINGER AND THUMB, THE EMULSION SIDE UP, HELD UNDER TENSION, AND

SLIPPED OVER BOTH PINS SIMULTANEOUSLY. IT IS THEN PUSHED DOWN INTO CONTACT WITH THE TOP PLATE OF THE GAGE, WITH THE THUMB-NAILS PRESSING LIGHTLY ON THE OUTSIDE OF THE PINS. THE INSTRUMENT IS THEN TAPPED LIGHTLY WITH THE FINGER OR A PENCIL TO ELIMINATE FRICTION OR STICKING IN THE DIAL GAGE. THE DIAL GAGE, GRADUATED TO THOUSANDTHS OF AN INCH, WAS READ TO TEN THOUSANDTHS OF AN INCH. THE STRIP IS REMOVED FROM THE INSTRUMENT BY GRASPING THE ENDS AS BEFORE, AND HOLDING IT UNDER TENSION WHILE LIFTING IT OFF THE TWO PINS SIMULTANEOUSLY. THESE OPERATIONS CONSUME ONLY ABOUT 10 SECONDS.

THE STRIPS ARE KEPT HANGING UP SEVERAL FEET AWAY FROM THE OBSERVER EXCEPT DURING THE ACTUAL OPERATIONS OF MEASUREMENT, SO THAT THE EFFECT OF MOISTURE FROM THE OBSERVER'S BREATH AND BODY ON THEIR DIMENSIONS WILL BE SMALL. THE ZERO OF THE PIN GAGE SHOULD BE CHECKED EACH TIME A SERIES OF MEASUREMENTS IS MADE BY NOTING THE READINGS ON THE DIAL GAGE WHEN THE MOVABLE PIN IS DISPLACED TO ITS IMPOSED LIMITS. IN THE PRESENT STUDY THESE READINGS NEVER VARY BY MORE THAN 0.0002 OF AN INCH, SO NO ZERO CORRECTION WAS EVER FOUND NECESSARY.

TO TEST THE REPRODUCIBILITY OF MEASUREMENTS MADE ON THE PIN GAGE, 10 STRIPS OF FILM, FIVE CUT CROSSWISE AND FIVE LENGTHWISE, WERE CONDITIONED, PUNCHED WITH TWO PAIRS OF HOLES IN EACH, AND MEASURED. THEY WERE THEN KEPT IN THE CONDITIONING ROOM (UNPROCESSED) AND REMEASURED SEVEN TIMES DURING A PERIOD OF EIGHT DAYS. THE DEVIATION OF THE CHANGE IN SPACING FROM THE INITIAL MEASUREMENT FROM THE AVERAGE CHANGE BETWEEN 10 PAIRS OF HOLES MEASURED AT THE SAME TIME WAS RECORDED. THERE WERE 70 SUCH DETERMINATIONS IN EACH DIRECTION. THE R. M. S. PROBABLE ERROR OF A SINGLE MEASUREMENT WAS DERIVED AS 0.00018 INCH IN THE CROSSWISE AND 0.00016 IN THE LENGTHWISE DIRECTION. BASED ON A DISTANCE OF EIGHT INCHES BETWEEN HOLES THESE ARE 0.0022 AND 0.0020 PERCENT, RESPECTIVELY, BUT LITTLE IF ANY GREATER THAN THE ERROR TO BE EXPECTED IN ESTIMATING TEN THOUSANDTHS FROM A SCALE GRADUATED TO THOUSANDTHS OF AN INCH.

THE OPTICAL GAGE WAS USED TO MEASURE THE DIMENSIONAL CHANGE OF BOTH PAPERS AND FILMS. EACH SAMPLE WAS MEASURED BETWEEN SIX PAIRS OF INTERSECTIONS, THREE CROSSWISE AND THREE LENGTHWISE, THE SERIES OF SIX MEASUREMENTS ON A SINGLE SAMPLE REQUIRING TWO OR THREE MINUTES. THE SAMPLES WERE KEPT HANGING UP SEVERAL FEET TO ONE SIDE OF THE OBSERVER EXCEPT WHEN BEING MEASURED. AS PREVIOUSLY MENTIONED, BOTH BEFORE AND AFTER A GROUP OF SAMPLES WAS MEASURED ON THE OPTICAL GAGE, THE ZERO OF THE INSTRUMENT WAS CHECKED BY MEASURING A PRINT OF THE SAME GRID ON A GLASS POSITIVE (REFERENCE STANDARD). FROM THE DEVIATIONS OF THE INDIVIDUAL PAIRS OF MEASUREMENTS ON THE REFERENCE STANDARD, THE PROBABLE ERROR OF A SINGLE MEASUREMENT ON THE INSTRUMENT WAS COMPUTED. BASED UPON 20 PAIRS OF MEASUREMENTS OF THE PLATE, OR 240 INDIVIDUAL MEASUREMENTS, THE PROBABLE ERROR HERE WAS 0.00009 INCH, OR 0.0015 PERCENT OF THE 6-INCH GAGE LENGTH. AS WITH THE PIN GAGE, THIS ALSO IS NOT GREATER THAN THE ERROR TO BE EXPECTED IN ESTIMATING TEN THOUSANDTHS ON A SCALE GRADUATED TO THOUSANDTHS OF AN INCH.

THE PROBABLE ERRORS OF BOTH INSTRUMENTS ARE ABOUT 0.002 PERCENT. THE FILM DIMENSIONS OF THE FILM ITSELF, HOWEVER, ARE NOT NEARLY SO REPRODUCIBLE WHEN ITS SURROUNDING CONDITIONS ARE CHANGED. A GROUP OF 10 STRIPS OF FILM WAS HUNG ON A LINE FOR 24 HOURS IN THE CONDITIONING ROOM, MEASURED AND REHUNG. A 40-WATT LAMP WAS PLACED AT A DISTANCE VARYING FROM ONE TO TWO FEET FROM THE FILM SAMPLES AND KEPT BURNING FOR SEVERAL HOURS. THE LAMP WAS REMOVED AND AFTER A PERIOD OF 24 HOURS THE FILMS WERE AGAIN MEASURED. THE PROBABLE FLUCTUATIONS OF THE MEASUREMENTS WERE THEN 0.004 PERCENT CROSSWISE AND 0.008 PERCENT LENGTHWISE IN EIGHT INCHES, FROM TWO TO FOUR TIMES THE PROBABLE ERROR OF THE GAGES. THE PROBABLE FLUCTUATION OF THE MEASURED DIMENSIONAL CHANGE OF A STRIP OF FILM DUE TO OVEN TREATMENT AT 120°F FOR SEVEN DAYS WAS COMPUTED FOR SEVERAL GROUPS OF 10 STRIPS OF FILM AND WAS FOUND TO BE ABOUT 0.02 TO 0.04 PERCENT. THIS IS ABOUT 10 TO 20 TIMES THE ERROR OF THE INSTRUMENTS.

THE MEASUREMENTS USED IN COMPUTING THE PROBABLE ERRORS OF THE GAGES WERE MADE BY AN OBSERVER WHO MADE SEVERAL THOUSAND MEASUREMENTS ON EACH OF THE TWO INSTRUMENTS, AND HENCE HAD ACQUIRED THE TECHNIQUE OF HANDLING THE STRIPS RAPIDLY AND PRECISELY. PRECAUTIONS WERE TAKEN TO ELIMINATE AS MUCH AS POSSIBLE

THE EFFECT OF HEAT FROM THE LAMP AND MOISTURE FROM THE OBSERVER'S BODY AND BREATH ON THE SAMPLES OF FILM. IF THESE PRECAUTIONS ARE NOT TAKEN THE FLUCTUATIONS WILL, OF COURSE, BE LARGER.

FILM SHRINKAGE AS A FUNCTION OF CONDITIONING TIME

IT IS WELL KNOWN THAT PHOTOGRAPHIC FILM CHANGES IN DIMENSION WITH CHANGE IN MOISTURE CONTENT AND THAT THE AMOUNT OF MOISTURE IN THE FILM TENDS TO FOLLOW A CHANGE IN THE ATMOSPHERE. HOWEVER, NO INFORMATION ON THE TIME REQUIRED FOR THE FILM TO REACH EQUILIBRIUM WAS AVAILABLE.

THE RATE OF APPROACH TO DIMENSIONAL EQUILIBRIUM WITH HUMIDITY WAS INVESTIGATED FOR 3 DIFFERENT FILMS; REGULAR, TOPOGRAPHIC, AND SPECIAL LOW SHRINKAGE FILM. THESE FILMS WERE ALL IN ROLLS 9-1/2 INCHES WIDE AND 25 FEET LONG. TEST STRIPS OF THESE WERE CONDITIONED AT 65% RELATIVE HUMIDITY AND PROCESSED. WHEN THOROUGHLY DRY THE STRIPS WERE PUT EACH IN A PAPER ENVELOPE AND KEPT IN AN OVEN AT 120°F FOR 24 HOURS, PUT IN AN OPEN CAN AND REPLACED IN THE OVEN FOR AN ADDITIONAL 24 HOURS. AT THE END OF THIS PERIOD THE CAN WAS QUICKLY COVERED, SEALED WITH TAPE AND TRANSFERRED TO THE CONDITIONING ROOM WHERE IT WAS OPENED AND THE FILM STRIPS MEASURED IMMEDIATELY, NOTING THE TIME. WHILE THE MOISTURE IN THE FILM WAS COMING TO EQUILIBRIUM WITH THE AIR IN THE CONDITIONING ROOM, A SERIES OF MEASUREMENTS WERE MADE, EXTENDING OVER A PERIOD OF 16 DAYS. FROM THESE MEASUREMENTS WAS COMPUTED THE DIMENSIONAL CHANGE OF THE FILMS, BASED ON THEIR ORIGINAL MEASUREMENT BEFORE PROCESSING.

THE RESULTS FOR ONE, THE TOPOGRAPHIC FILM, SHOWN IN FIGURE 8, WERE PLOTTED ON A LINEAR SCALE AS DIMENSIONAL CHANGE IN PERCENT AGAINST TIME UP TO ABOUT SEVEN HOURS. THESE CURVES, RISING STEEPLY FOR AN HOUR OR TWO AND THEN LEVELING OFF, SEEM TO INDICATE THAT EQUILIBRIUM IS APPROXIMATELY REACHED WITHIN A FEW HOURS. HOWEVER, THIS IS NOT STRICTLY TRUE. THE RESULTS FROM ALL THREE FILMS, SHOWN IN FIGURES 9, 10, AND 11, WERE PLOTTED AS DIMENSIONAL CHANGE IN PERCENT AGAINST THE LOGARITHM OF THE CONDITIONING TIME, UP TO 16 DAYS. THESE CURVES SHOW THAT DIMENSIONAL EQUILIBRIUM WAS NOT REACHED EVEN AFTER TWO WEEKS' CONDITIONING, AND THAT ABOUT 100 DAYS WOULD BE REQUIRED TO ESTABLISH EQUILIBRIUM. IT MAY BE POINTED OUT THAT THIS CHANGE IS DUE TO LACK OF MOISTURE EQUILIBRIUM, AND NOT TO LOSS OF SOLVENT FROM THE FILM BASE. SUCH LOSS OF SOLVENT RESULTS IN A SHRINKAGE OF THE FILM, WHILE IN THIS CASE THE FILM IS EXPANDING.

THESE EXPERIMENTS SHOW THAT CONDITIONING TIME IS AN IMPORTANT FACTOR AND THAT A DEFINITE TIME SHOULD BE STATED IN ANY SPECIFICATION WHICH MAY BE PREPARED FOR AERIAL FILM SHRINKAGE TESTS. OBVIOUSLY, MOISTURE EQUILIBRIUM WITH THE SURROUNDING AIR CANNOT BE SPECIFIED. HOWEVER, 24 OR 48 HOURS CONDITIONING SHOULD BE SATISFACTORY FOR TESTING PURPOSES.

FILM SHRINKAGE AS A FUNCTION OF ACCELERATED AGING TIME

THE EFFECT OF ACCELERATED AGING AT 120°F FOR FROM ONE TO 32 DAYS UPON THE DIMENSIONS OF AERO FILM WERE STUDIED. FOR THIS EXPERIMENT A REGULAR AND A TOPOGRAPHIC FILM WERE CHOSEN. SIX SAMPLES OF EACH 8 x 9-1/2 INCHES WERE CUT AND CONDITIONED IN A LIGHT-TIGHT CABINET WITH FORCED VENTILATION FOR 48 HOURS AT 72°F, 65% RELATIVE HUMIDITY. THESE WERE THEN EXPOSED IN CONTACT WITH THE GRID NEGATIVE, DEVELOPED IN A METOL-HYDROQUINONE DEVELOPER FOR TWO MINUTES AT 21°C, RINSED IN A DILUTE ACETIC ACID SHORT STOP BATH, FIXED FOR 12 MINUTES IN AN ACID HARDENING FIXING BATH, WASHED 30 MINUTES IN RUNNING WATER, AND DRIED OVER NIGHT, IN THE LABORATORY. AFTER RECONDITIONING FOR 48 HOURS AT 72°F, 65% RELATIVE HUMIDITY, THE SAMPLES WERE MEASURED ON THE OPTICAL GAGE. AFTER MEASURING, THE FILMS WERE PLACED EACH IN A PAPER ENVELOPE IN AN OVEN MAINTAINED AT 120°F (49°C) AND ONE SAMPLE FROM EACH ROLL REMOVED AFTER ONE, TWO, FOUR, NINE, 16 AND 32 DAYS, RESPECTIVELY. EACH SAMPLE WAS THEN RECONDITIONED AT 72°F, 65% RELATIVE HUMIDITY FOR 48 HOURS AND AGAIN MEASURED ON THE OPTICAL GAGE.

THE SHRINKAGE OF THE FILMS DUE TO OVEN TREATMENT WAS COMPUTED FROM THE DIFFERENCE IN THE DIMENSION OF THE FILM AFTER PROCESSING AND AFTER OVEN TREATMENT. THE RESULTS IN FIGURE 12 WERE PLOTTED WITH SHRINKAGE IN PERCENT AS ORDINATES AND THE LOGARITHM OF THE TIME IN THE OVEN IN DAYS AS ABSCISSAS. IT WILL BE NOTED THAT THE POINTS LIE APPROXIMATELY ON A STRAIGHT LINE. THE

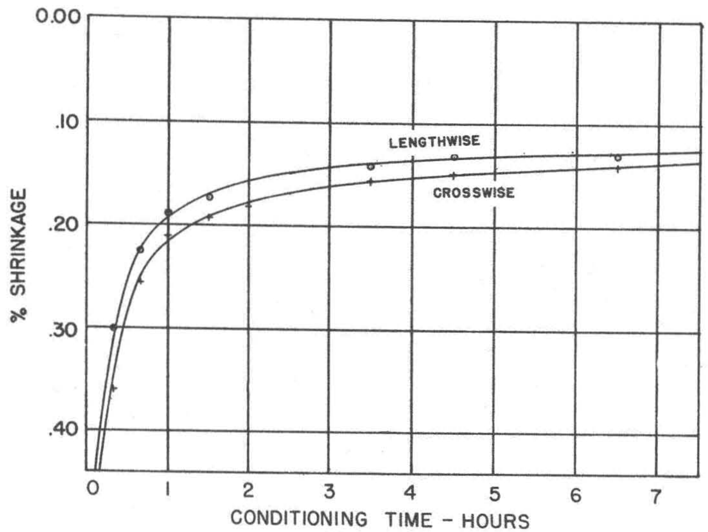


Figure 8
Graph showing percent shrinkage as a function of conditioning time for special aero film

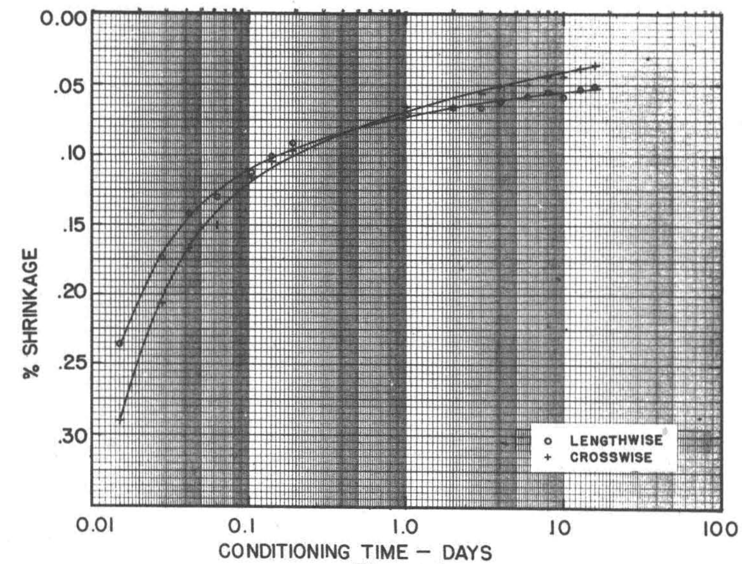


Figure 9
Graph showing percent shrinkage as a function of the log of conditioning time for topographic film

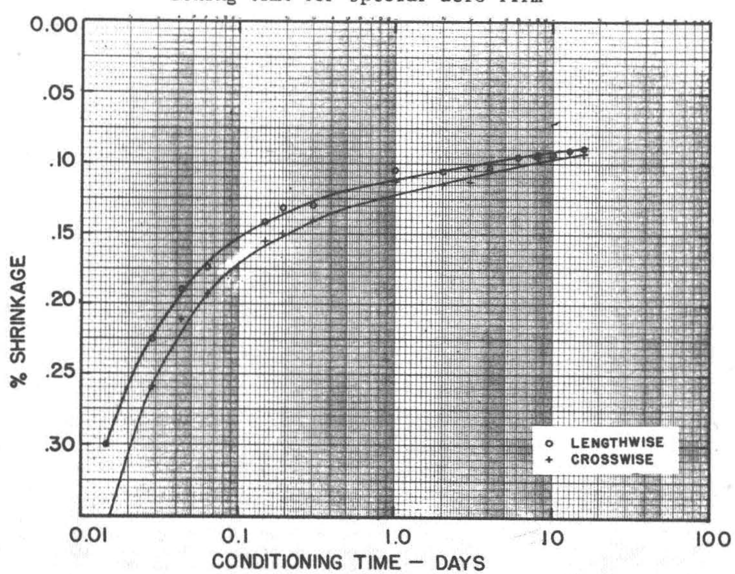


Figure 10
Graph showing percent shrinkage as a function of the log of conditioning time for special aero film.

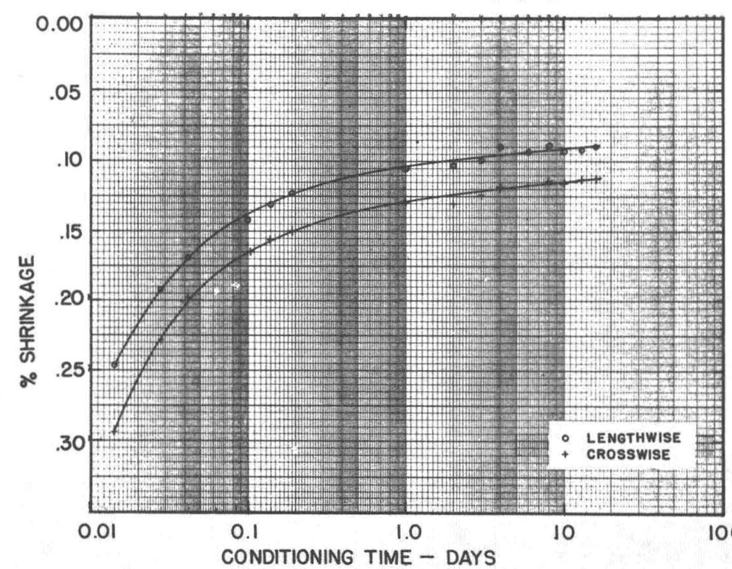


Figure 11
Graph showing percent shrinkage as a function of the log conditioning time for regular aero film

SHRINKAGE IS SEEN TO BE GREATER IN THE CROSSWISE DIRECTION, AND THE RATE OF SHRINKAGE IS GREATER IN THE CROSSWISE DIRECTION, FOR BOTH FILMS. THE SHRINKAGE OF THE REGULAR FILM IS MUCH GREATER THAN THE TOPOGRAPHIC FILM AND ALSO ITS RATE OF SHRINKAGE IS SLIGHTLY HIGHER.

THE POSITION OF THE LINES THROUGH THE POINTS IN FIGURE 12 WAS OBTAINED BY LEAST SQUARES. THE SAME DATA WERE ALSO PLOTTED ON A LINEAR TIME SCALE IN FIGURE 13. THE SOLID LINES IN THIS FIGURE ARE TRANSFORMED FROM THE STRAIGHT LINES IN FIGURE 12. THE DASHED PORTIONS OF THE CURVES ARE ESTIMATES OF THE BEHAVIOR OF THE FILMS IN THE OVEN FOR LESS THAN ONE DAY, AND OF COURSE, THIS MAY NOT BE EXACT.

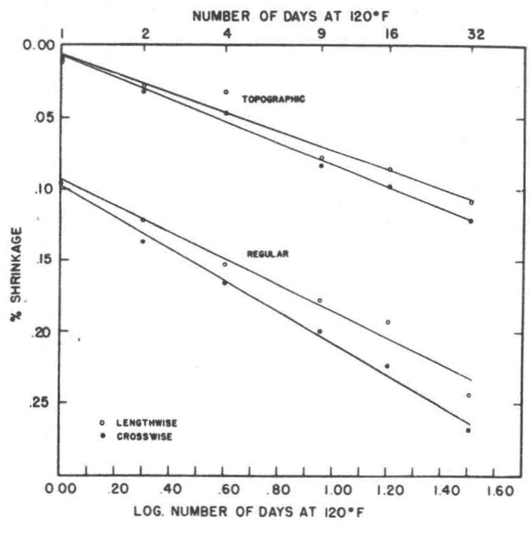


Figure 12
Illustrating the linear relation between percent shrinkage and the log of time in days of accelerated aging for regular and topographic base film.

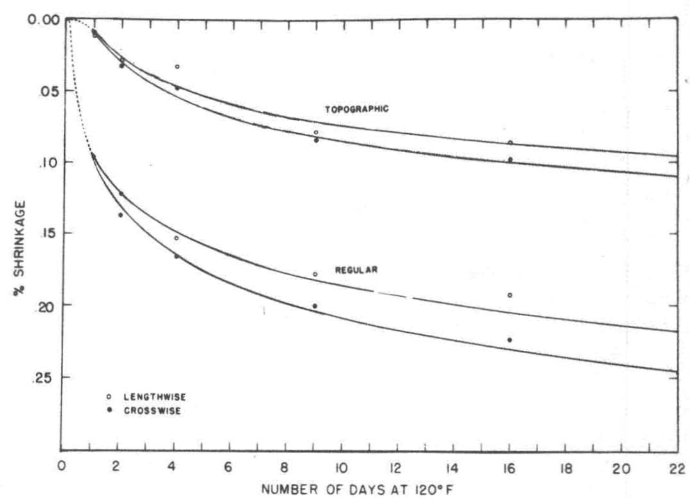


Figure 13
The curves of figure 12 plotted on a linear scale of accelerated aging time in days to show that a large shrinkage occurs during the first day of aging.

SHRINKAGE OF AERO FILMS AS A FUNCTION OF RELATIVE HUMIDITY

IN CONNECTION WITH A SEPARATE PROJECT, THE CONDITIONING ROOM ORDINARILY MAINTAINED AT 50% RELATIVE HUMIDITY WAS TO BE OPERATED AT A SERIES OF RELATIVE HUMIDITIES. THE PROGRAM CALLED FOR PERIODS OF APPROXIMATELY A WEEK'S DURATION AT 32%, 43%, 65%, 76%, 86%, 65% AND 50% RELATIVE HUMIDITY, THE TEMPERATURE TO BE KEPT CONSTANT AT $72^{\circ}C$. ADVANTAGE WAS TAKEN OF THIS TO DETERMINE THE FILM SHRINKAGE UNDER THESE CONDITIONS.

17 SAMPLES OF AERO FILMS REPRESENTING SIX DIFFERENT BRANDS OF FILMS WERE STUDIED. SOME OF THESE SAMPLES HAD ALREADY BEEN USED FOR OTHER PURPOSES AND CONSEQUENTLY HAD BEEN CUT, CONDITIONED AND PUNCHED FOR SOME TIME. IN EACH CASE, ONE GROUP OF TEST STRIPS WAS LEFT IN THE CONDITIONING ROOM UNPROCESSED AND ANOTHER GROUP EITHER PROCESSED ONLY, OR PROCESSED AND GIVEN AN OVEN TREATMENT AT $120^{\circ}F$, THEN LEFT IN THE CONDITIONING ROOM UNTIL THE START OF THE CYCLE OF RELATIVE HUMIDITIES. THE HISTORY OF THESE FILMS PRIOR TO THESE TESTS WAS AS FOLLOWS:

SAMPLES C AND Q: CONDITIONED AT 65% RELATIVE HUMIDITY;
UNPROCESSED FILMS CONDITIONED 53 DAYS;
FILMS OVEN TREATED FOR SEVEN DAYS, RECONDITIONED 42 DAYS;
FILMS OVEN TREATED FOR 14 DAYS, RECONDITIONED 35 DAYS.

SAMPLE F: CONDITIONED AT 50% RELATIVE HUMIDITY;
UNPROCESSED FILMS CONDITIONED 22 DAYS;
FILMS OVEN TREATED FOR SEVEN DAYS, RECONDITIONED 11 DAYS.

Sample G: Conditioned at 50% relative humidity;
Unprocessed films conditioned 19 days;
Films oven treated for seven days, reconditioned nine days;

Sample I: Conditioned at 50% relative humidity;
Unprocessed films conditioned 11 days;
Films oven treated for seven days, reconditioned two days;

Sample J: Unprocessed films conditioned eight days at 50% relative humidity;
Films oven treated for seven days started in cycle of humidities at 32% immediately after removing from oven.

Sample O: Conditioned at 50% relative humidity;
Unprocessed films conditioned 24 days;
Films oven treated for seven days reconditioned 15 days.

12 Samples - A, B, C, H, K, N, P, Q, R, S, T, and U:
Conditioned at 50% relative humidity;
Unprocessed films conditioned three days;
Processed films reconditioned two days;

Having received the described treatments all films were conditioned at the relative humidities as follows before measuring:

3 days at 32%	4 days at 43%	7 days at 50%
10 days at 65%	7 days at 76%	5 days at 86%
7 days at 65%	7 days at 50%	

Immediately before the room was changed to a new humidity condition, the film samples were placed in sealed cans where they remained until the new condition had been established.

The dimensional changes of the films were computed and tabulated as change from the original measurements made on the films at 50 or 65% relative humidities. The results are given in Table I. Each value in the table is the average of 10 measurements on the film. The results on six of these films were plotted as dimensional change in percent against relative humidity in figures 14 to 19. Unprocessed films are shown by full lines, films only processed by dashed lines and films processed and oven treated by dotted lines.

It was expected that the films should show a hysteresis effect when the humidity was varied, that is, the dimensional changes of the film should lag behind the changes of relative humidity. Ordinarily a curve showing the relation between cause and effect in a material which exhibits hysteresis is an S-shaped curve or a lenticular shaped curve. The curves of figures 14 to 19 as a whole do not properly fit this description, but it must be remembered that this series of measurements at different relative humidities was made over a long period of time (about nine weeks) and that the films were losing some solvent, consequently, shrinking somewhat all the time. The rate of shrinkage due to this cause is probably not the same at different humidities, and therefore, it would be difficult to make a correction for it. This shrinkage is suggested in that the descending portions of most of the curves shown lie below the ascending portions, instead of above them as in the case of hysteresis curves of paper. With this in mind it can be seen that certain of the curves, sample N, figure 14; the oven treated test strips of sample C, figure 15; and sample O, figure 17, are S-shaped.

At the 76% relative humidity and above, most of the curves seem erratic. In these cases, the observed expansion is too high, probably due to the gelatin which takes on water more readily than the celluloid, and being in contact with the celluloid may have the effect of accelerating the hydration. The hydration and dehydration of gelatin is accompanied with larger expansion and contraction than celluloid. This effect is illustrated in figure 20, which shows four bottles, each containing two strips of film, one cut lengthwise and the other cut crosswise from the roll. The bottles are closed and each contains a solution to maintain a fixed vapor pressure. The relative humidities are, from left to right, 11%, 37%, 77%, and 88%. The emulsion sides of the films are to the right. It will be noticed that the film cut lengthwise tends to uncurl as the humidity increases. The sample cut crosswise actually bends backward in the 88% bottle. At about 65 to 70% relative humidity films do not curl.

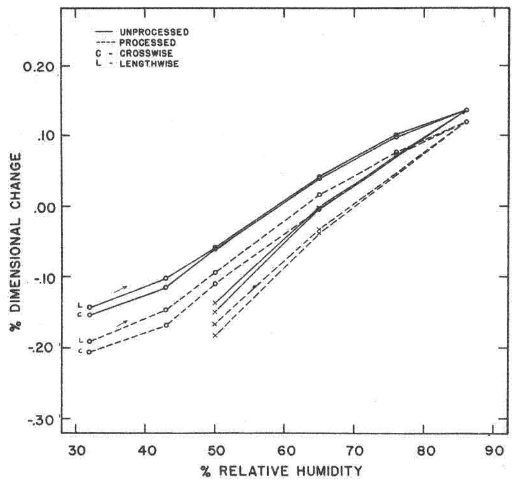


Figure 14
Percent shrinkage-relative humidity for a regular base infra-red sensitive film (Sample N, Table1).

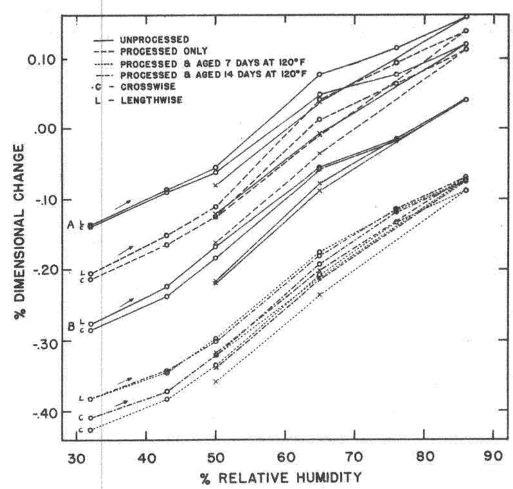


Figure 15
Percent shrinkage-relative humidity for a regular base aero film (Sample C, Table 1)

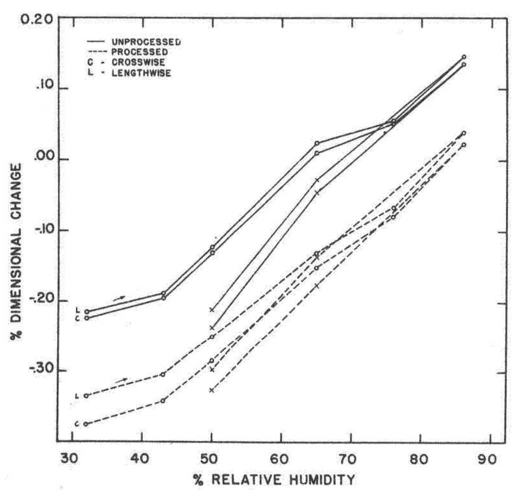


Figure 16
Percent shrinkage-relative humidity for a regular base aero film (Sample G, Table 1)

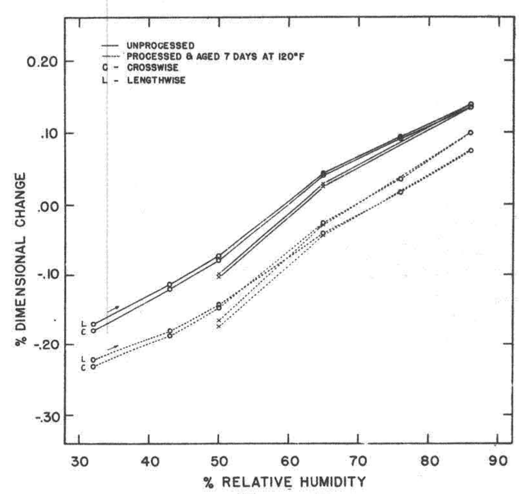


Figure 17
Percent shrinkage-relative humidity for topographic base aero film (Sample O, Table 1)

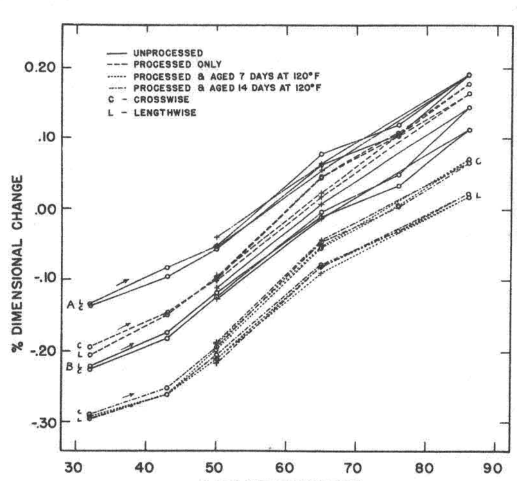


Figure 18
Percent shrinkage-relative humidity for a topographic base aero film (Sample Q, Table 1)

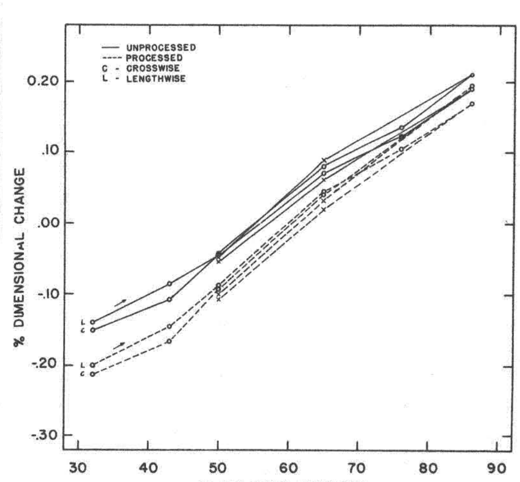


Figure 19
Percent shrinkage-relative humidity for a topographic base aero film (Sample R, Table 1)

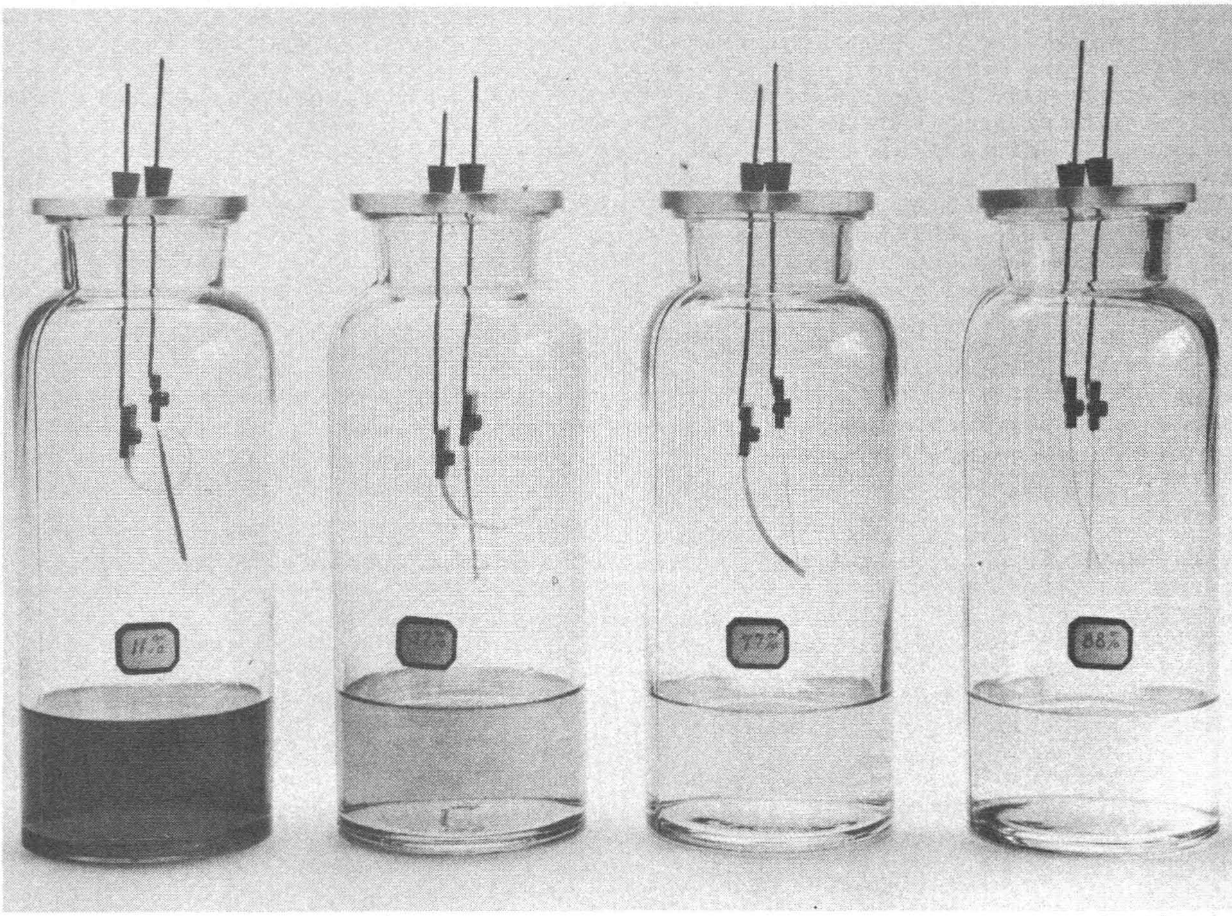


Figure 20

Illustrating the fact that gelatin has larger expansion and contraction than celluloid with changes in relative humidity. Gelatin side of films is to the right. Each bottle contains two samples of film, one cut lengthwise and one cut crosswise. From left to right the relative humidity condition in the bottles is 11%, 37%, 77%, and 88%. The sample cut lengthwise uncurls with increasing moisture.

Film Shrinkage Due to Processing and Accelerated Aging

The effect of processing and of accelerated aging upon the dimensions of aero film was investigated. Accelerated aging consists of keeping the film in an oven at 120°F (49°C) for seven days. Two sets of conditions were imposed, one in which the films were doncitioned at 50% relative humidity and 72°F, and another in which they were conditioned at 65% relative humidity and 72°F.

For the determinations at 50% relative humidity, samples were taken from 21 different rolls of film, having different emulsion numbers, representing six different types. Test strips were conditioned at 50% relative humidity and 72°F for one or two days, measured, processed, reconditioned for two days, and remeasured. Then one group of film strips was kept in an oven at 120°F (49°C) for one to two days, and remeasured to determine the shrinkage due to oven treatment (accelerated aging).

For the shrinkage determinations at 65% relative humidity, 8 x 9-1/2 inch samples were taken from the same 21 rolls of film, and also one sample each from three 8 x 10 inch cut films. One of them, sample X, is a chloride emulsion on a cellulose acetate base loaded with some material to make it

WHITE AND FAIRLY OPAQUE. ITS SHRINKAGE IS ABOUT THE SAME AS LOW SHRINK BASE. TWO SEPARATE DETERMINATIONS WERE MADE. THE SAMPLES WERE CONDITIONED AT 65% RELATIVE HUMIDITY AND 72°F IN A LIGHT-TIGHT CABINET WITH FORCED VENTILATION FOR 64 HOURS AND 48 HOURS, RESPECTIVELY, THEN EXPOSED IN CONTACT WITH A NEGATIVE OF A MAX LEVY RULED GLASS GRID COMPOSED OF LINES 1/2 INCH APART. THEY WERE DEVELOPED 2-1/4 MINUTES IN A METOL-HYDROQUINONE DEVELOPER, RINSED IN DILUTE ACETIC ACID SHORT STOP BATH, FIXED 12 MINUTES, WASHED 1/2 TO ONE HOUR IN RUNNING WATER AND DRIED IN THE LABORATORY. THEN THEY WERE HUNG UP AND CONDITIONED FOR 21 AND 44 HOURS, RESPECTIVELY, AT 65% RELATIVE HUMIDITY AND 72°F, AND MEASURED ON THE OPTICAL GAGE TO OBTAIN THE DIMENSIONAL CHANGE DUE TO PROCESSING. AFTER MEASURING THEY WERE PLACED IN THE OVEN FOR SEVEN DAYS AT 120°F (49°C) FOLLOWED BY TWP DAYS RECONDITIONING AT 65% RELATIVE HUMIDITY, 72°C, AND AGAIN MEASURED, TO OBTAIN THE DIMENSIONAL CHANGE DUE TO ACCELERATED AGING.

THE RESULTS OF THE MEASUREMENTS IN TABLES 2 AND 3 WERE COMPUTED AND TABULATED AS DIMENSIONAL CHANGE, IN PERCENT, IN THE CROSSWISE DIRECTION, LENGTHWISE DIRECTION AND THE DIFFERENCE BETWEEN THE TWO DIRECTIONS DUE TO PROCESSING ALONE, AND DUE TO PROCESSING AND ACCELERATED AGING.

THE SHRINKAGE OF FILMS BASED UPON MEASUREMENTS AT 50% RELATIVE HUMIDITY (TABLE 2) IS MUCH GREATER THAN THE SHRINKAGE BASED ON MEASUREMENTS AT 65% (TABLE 3). FOR INSTANCE, AT 65% RELATIVE HUMIDITY, ALL THE SAMPLES OF AERO FILM WOULD PASS AIR CORPS SPECIFICATION NO. 31004B WITH RESPECT TO SHRINKAGE, WHILE AT 50%, EIGHT SAMPLES WOULD NOT HAVE PASSED SPECIFICATIONS. THIS SHOWS THE NEED OF SPECIFYING THE CONDITIONS UNDER WHICH SHRINKAGE IS TO BE MEASURED IF THE SPECIFICATIONS ARE TO HAVE DEFINITE MEANING.

THE SHRINKAGE OF THE AERO FILM ON SPECIAL LOW SHRINK BASE IS JUST AS LARGE AS THAT OF THE TOPOGRAPHIC AERO FILM BOTH IN AMOUNT OF SHRINKAGE AND DIFFERENTIAL SHRINKAGE. THE AMOUNT OF SHRINKAGE IS PERHAPS A LITTLE GREATER FOR THE SPECIAL LOW SHRINK BASE.

SHRINKAGE OF PHOTOGRAPHIC PAPERS DUE TO PROCESSING

THE EFFECT OF PROCESSING UPON THE DIMENSIONS OF PHOTOGRAPHIC PRINTING PAPERS WAS INVESTIGATED FOR 32 DIFFERENT SAMPLES OF CONTACT PRINTING PAPERS AND 25 DIFEERENT SAMPLES OF PROJECTION PAPERS. THESE WERE IN SHEETS 8 x 10 INCHES. HE PAPER SAMPLES WERE CONDITIONED IN A LIGHT-TIGHT CONDITIONING CABINET WITH FORCED VENTILATION, FOR 24 HOURS AT 65% RELATIVE HUMIDITY, 72°F. THEY WERE THEN EXPOSED IN CONTACT WITH THE GRID. THEY WERE PROCESSED AS FOLLOWS: CONTACT PAPERS DEVELOPED 45 SECONDS, PROJECTION PAPERS, 1.5 MINUTES, RINSED IN ACETIC ACID SHORT STOP BATH, FIXED ABOUT 12 MINUTES, WASHED IN RUNNING WATER FOR AN HOUR, SURFACE WATER BLOTTED OFF, DRIED ON CHEESE CLOTH COVERING DRYING RACKS IN UNCONTROLLED ATMOSPHERE AND RETURNED TO THE CONDITIONING ROOM. AFTER RECONDITIONING FOR SEVERAL DAYS AT 65% RELATIVE HUMIDITY AND 72°F THE PAPERS WERE MEASURED ON THE OPTICAL GAGE. THE DISTANCE BETWEEN THE LINES SIX INCHES APART WAS MEASURED AT THE CENTER, AND ALSO ABOUT ONE INCH FROM EACH EDGE, IN BOTH DIRECTIONS, CROSSWISE AND LENGTHWISE.

THE RESULTS OF THE MEASUREMENTS GIVEN IN TABLES 4 AND 5 WERE COMPUTED AND TABULATED AS DIMENSIONAL CHANGE OF THE PAPERS IN PERCENT, DUE TO PROCESSING, ALONG THE MACHINE DIRECTION, ACROSS THE MACHINE DIRECTION, AND THE DIFFERENCE BETWEEN THE CHANGES IN THE TWO DIRECTIONS.

THE FOLLOWING PAPERS WERE FOUND TO HAVE VERY SMALL SHRINKAGE: BRAND Z, A BROMIDE PAPER, IS A LAMINATED MATERIAL COMPOSED OF A SHEET OF HARD ALUMINUM FOIL CEMENTED BETWEEN PAPER. ITS SHRINKAGE DUE TO PROCESSING WAS LESS THAN .01%. ONE SAMPLE WAS DRIED IN THE OVEN AT 120°F FOR 24 HOURS AND REMEASURED. IT SHRANK ONLY .03% AND .01%, RESPECTIVELY, IN TWO DIRECTIONS AT RIGHT ANGLES. BRAND X IS A WATERPROOF PAPER, MADE WITH CONTACT OR ENLARGMENT EMULSIONS. THE SHRINKAGE OF THE CONTACT AND ENLARGING PAPERS DUE TO PROCESSING WAS .02%, .03% ALONG AND .01%, .02% ACROSS THE SHEET, RESPECTIVELY. THEIR SHRINKAGE DUE TO 24 HOURS IN THE OVEN AT 120°F WAS .02% AND .03% ALONG AND .07% AND .06% ACROSS THE SHEET, RESPECTIVELY.

THE REST OF THE PAPERS WERE FOUND TO HAVE A MAXIMUM SHRINKAGE RANGING FROM ABOUT .20% TO .50%, FOUR PAPERS BEING IN EXCESS OF .50%. THE DIFFERENTIAL SHRINKAGE OF THE PAPERS, (I. E., THE DIFFERENCE IN SHRINKAGE IN TWO

TABLE 1.- (Continued)

RELATIVE HUMIDITY	32%	43%	50%	65%	76%	86%	65%	50%
Regular film base								
Ss. panchromatic								
Infra-red sensitive								
Sample N								
Unprocessed								
Crosswise	-.154	-.115	-.060	+.040	+.098	+.136	-.004	-.149
Lengthwise	-.143	-.102	-.059	+.038	+.100	+.136	-.003	-.137
Processed								
Crosswise	-.206	-.168	-.110	-.004	+.072	+.119	-.038	-.182
Lengthwise	-.191	-.147	-.094	+.017	+.076	+.119	-.033	-.166
Topographic film base								
Ss. panchromatic								
Sample O								
Unprocessed								
Crosswise	-.179	-.120	-.080	+.040	+.091	+.134	+.025	-.103
Lengthwise	-.169	-.113	-.073	+.043	+.093	+.138	+.028	-.098
Oven treated 7 days								
Crosswise	-.231	-.187	-.147	-.027	+.034	+.099	-.030	-.164
Lengthwise	-.221	-.180	-.142	-.042	+.016	+.073	-.045	-.173
Sample P								
Unprocessed								
Crosswise	-.155	-.094	-.051	+.060	+.095	+.176	+.054	-.067
Lengthwise	-.151	-.095	-.048	+.086	+.130	+.201	+.085	-.048
Processed								
Crosswise	-.215	-.151	-.102	+.025	+.085	+.170	+.011	-.121
Lengthwise	-.207	-.152	-.088	+.050	+.109	+.183	+.032	-.098
Sample Q								
Unprocessed								
Crosswise	-.136	-.096	-.057	+.063	+.106	+.191	+.055	-.053
Lengthwise	-.134	-.083	-.053	+.077	+.119	+.192	+.064	-.040
Processed								
Crosswise	-.194	-.146	-.100	+.045	+.108	+.178	+.023	-.095
Lengthwise	-.205	-.149	-.097	+.046	+.103	+.164	+.017	-.101
Unprocessed								
Crosswise	-0.225	-0.182	-0.124	-0.004	+0.049	+0.144	+0.007	-0.111
Lengthwise	-.221	-.174	-.118	-.011	+.033	+.112	-.007	-.126
Oven treated 7 days								
Crosswise	-.290	-.252	-.194	-.047	+.004	+.065	-.045	-.188
Lengthwise	-.295	-.260	-.205	-.079	-.030	+.022	-.081	-.216
Oven treated 14 "								
Crosswise	-.293	-.261	-.197	-.055	+.005	+.070	-.053	-.190
Lengthwise	-.296	-.261	-.211	-.082	-.031	+.017	-.091	-.211
Sample R								
Unprocessed								
Crosswise	-.151	-.108	-.044	+.080	+.135	+.210	+.089	-.048
Lengthwise	-.140	-.086	-.045	+.071	+.122	+.190	+.062	-.054
Processed								
Crosswise	-.213	-.167	-.093	+.040	+.120	+.194	+.032	-.107
Lengthwise	-.200	-.146	-.088	+.045	+.104	+.169	+.020	-.100
Fine grain panchromatic								
Sample S								
Unprocessed								
Crosswise	-.138	-.094	-.048	+.068	+.115	+.214	+.087	-.045
Lengthwise	-.135	-.090	-.049	+.058	+.108	+.189	+.062	-.054
Processed								
Crosswise	-.193	-.142	-.082	+.040	+.106	+.202	+.044	-.096
Lengthwise	-.190	-.140	-.089	+.035	+.088	+.174	+.018	-.103
Low shrinkage film								
Ss. panchromatic								
Sample T								
Unprocessed								
Crosswise	-.148	-.098	-.075	+.042	+.095	+.159	+.004	-.132
Lengthwise	-.144	-.094	-.071	+.051	+.108	+.151	+.013	-.115
Processed								
Crosswise	-.219	-.170	-.134	+.012	+.084	+.130	-.036	-.187
Lengthwise	-.228	-.177	-.140	+.018	+.084	+.123	-.036	-.177
Sample U								
Unprocessed								
Crosswise	-.150	-.097	-.065	+.055	+.093	+.145	+.005	-.124
Lengthwise	-.166	-.109	-.077	+.068	+.106	+.158	+.027	-.099
Processed								
Crosswise	-.226	-.174	-.135	+.011	+.074	+.116	-.046	-.188
Lengthwise	-.238	-.182	-.134	+.024	+.081	+.127	-.026	-.165

TABLE 1.- DIMENSIONAL CHANGE OF FILMS IN PER CENT AS A FUNCTION OF RELATIVE HUMIDITY

RELATIVE HUMIDITY	32%	43%	50%	65%	76%	86%	65%	50%
Regular film base Ss. panchromatic								
Sample.A								
Unprocessed								
Crosswise	-0.144	-0.089	-0.049	+0.059	+0.091	+0.155	+0.015	-0.110
Lengthwise	- .132	- .081	- .040	+ .085	+ .127	+ .180	+ .050	- .071
Processed								
Crosswise	- .212	- .159	- .116	+ .015	+ .070	+ .141	- .029	- .163
Lengthwise	- .186	- .133	- .085	+ .045	+ .104	+ .167	+ .014	- .103
Sample B								
Unprocessed								
Crosswise	- .166	- .111	- .063	+ .053	+ .082	+ .146	- .001	- .133
Lengthwise	- .149	- .099	- .046	+ .069	+ .107	+ .160	+ .023	- .104
Processed								
Crosswise	- .245	- .198	- .144	- .009	+ .049	+ .114	- .062	- .204
Lengthwise	- .199	- .152	- .106	+ .023	+ .070	+ .131	- .032	- .168
Sample C								
Unprocessed								
Crosswise	- .139	- .090	- .062	+ .048	+ .077	+ .119	- .007	- .121
Lengthwise	- .137	- .086	- .055	+ .077	+ .114	+ .158	+ .038	- .080
Processed								
Crosswise	- .214	- .165	- .125	+ .013	+ .063	+ .112	- .036	- .162
Lengthwise	- .206	- .152	- .111	+ .041	+ .094	+ .138	- .010	- .126
Unprocessed								
Crosswise	- .285	- .238	- .184	- .058	- .018	+ .040	- .088	- .219
Lengthwise	- .276	- .224	- .168	- .056	- .016	+ .041	- .078	- .217
Oven treated 7 days								
Crosswise	- .409	- .372	- .321	- .193	- .119	- .073	- .213	- .339
Lengthwise	- .382	- .344	- .301	- .181	- .115	- .070	- .202	- .318
Oven treated 14 "								
Crosswise	- .426	- .383	- .335	- .208	- .133	- .088	- .236	- .358
Lengthwise	- .382	- .346	- .297	- .176	- .117	- .073	- .212	- .321
Sample F								
Unprocessed								
Crosswise	- .168	- .114	- .074	+ .031	+ .061	+ .109	- .015	- .151
Lengthwise	- .144	- .092	- .058	+ .056	+ .095	+ .144	+ .023	- .116
Oven treated 7 days								
Crosswise	- .260	- .216	- .184	- .071	- .025	+ .035	- .098	- .226
Lengthwise	- .217	- .174	- .137	- .041	- .002	+ .062	- .062	- .187
Sample G								
Unprocessed								
Crosswise	- .224	- .195	- .130	+ .024	+ .052	+ .135	- .046	- .237
Lengthwise	- .216	- .189	- .122	+ .011	+ .056	+ .146	- .027	- .211
Oven treated 7 days								
Crosswise	- .377	- .342	- .285	- .151	- .078	+ .023	- .156	- .328
Lengthwise	- .336	- .305	- .251	- .130	- .066	+ .039	- .136	- .297
Sample H								
Unprocessed								
Crosswise	- .154	- .115	- .055	+ .044	+ .082	+ .136	+ .005	- .130
Lengthwise	- .143	- .103	- .040	+ .087	+ .140	+ .190	+ .070	- .067
Processed								
Crosswise	- .216	- .174	- .112	+ .007	+ .065	+ .132	- .039	- .183
Lengthwise	- .199	- .160	- .083	+ .048	+ .114	+ .174	+ .011	- .130
Sample I								
Unprocessed								
Crosswise	-0.141	-0.103	-0.038	+0.63	+0.121	+0.211	+0.077	-0.054
Lengthwise	- .121	- .086	- .023	+ .085	+ .139	+ .221	+ .091	- .028
Oven treated 7 days								
Crosswise	- .192	- .155	- .089	+ .012	+ .078	+ .183	+ .025	- .106
Lengthwise	- .154	- .118	- .068	+ .031	+ .080	+ .176	+ .028	- .090
Sample J								
Unprocessed								
Crosswise	- .145	- .106	- .053	+ .058	+ .115	+ .178	+ .068	- .058
Lengthwise	- .124	- .080	- .030	+ .092	+ .143	+ .201	+ .094	- .026
Oven treated 7 days								
Crosswise	- .202	- .158	- .100	+ .012	+ .076	+ .153	+ .020	- .113
Lengthwise	- .154	- .108	- .060	+ .035	+ .082	+ .150	+ .030	- .089
Sample K								
Unprocessed								
Crosswise	- .190	- .137	- .087	+ .038	+ .090	+ .193	- .003	- .064
Lengthwise	- .144	- .108	- .059	+ .043	+ .082	+ .148	+ .004	- .123
Processed								
Crosswise	- .261	- .207	- .151	+ .006	+ .081	+ .180	- .055	- .241
Lengthwise	- .191	- .156	- .101	+ .019	+ .061	+ .127	- .039	- .174

TABLE 2.- PER CENT SHRINKAGE OF AERO MAPPING FILM

Conditioned at 50% R.H., Temperature 72°F

Type of film	Processing only			Processing and oven treatment at 120°F		
	Cross-wise	Length-wise	Differ-ence	Cross-wise	Length-wise	Differ-ence
Regular film base Ss. panchromatic						
Sample A	0.07	0.05	0.02	0.14	0.09	0.05
" B	.11	.07	.04	.17	.15	.02
" C	.08	.06	.02	.20	.14	.06
" D	.08	.03	.05	.34	.27	.07
" E	.01	+.03	.04	.42	.27	.15
" F	.05	.03	.02	.16	.11	.05
" G	.04	.02	.02	.24	.22	.02
" H	.09	.07	.02	.16	.10	.06
" I	.01	.00	.01	.07	.05	.02
" J	.03	.00	.03	.10	.06	.04
" K	.10	.07	.03	.22	.18	.04
" L	.00	.01	.01	.18	.16	.02
" M	.-	.01	.-	.-	.23	.-
Infra-red sensitive						
Sample N	.07	.06	.01	.15	.13	.02
Topographic film base Ss. panchromatic						
Sample O	.03	.03	.00	.13	.13	.00
" P	.08	.07	.01	.14	.09	.05
" Q	.06	.06	.00	.11	.09	.02
" R	.08	.07	.01	.10	.10	.00
Fine grain panchromatic						
Sample S	.06	.07	.01	.10	.10	.00
Low shrink base Ss. panchromatic						
Sample T	.07	.08	.01	.18	.14	.04
" U	.07	.08	.01	.18	.15	.03

TABLE 3.- PER CENT SHRINKAGE OF AERO MAPPING FILM

Conditioned at 65% R.H., Temperature 72°F

	Processing only			Processing and oven treatment at 120°F		
	Cross-wise	Length-wise	Differ-ence	Cross-wise	Length-wise	Differ-ence
Regular film base Ss. panchromatic						
Sample A	0.03	0.04	0.02	0.14	0.14	0.00
" B	.03	.02	.01	.13	.11	.02
" C	.02	.02	.00	.14	.13	.01
" D	.05	.03	.02	.20	.18	.02
" E	.05	.02	.03	.18	.17	.01
" F	.02	.03	.01	.10	.12	.02
" G	.02	.01	.01	.19	.18	.01
" H	.03	.00	.03	.12	.08	.04
" I	.02	.00	.02	.06	.08	.02
" J	.00	.01	.01	.06	.07	.01
" K	+.01	.01	.02	.14	.12	.02
" L	.-	.02	.-	.-	.10	.-
" M	.-	.02	.-	.-	.19	.-
Infra-red sensitive						
Sample N	.02	.02	.00	.11	.11	.00
Topographic film base Ss. panchromatic						
Sample O	.00	.02	.02	.08	.09	.01
" P	.01	.01	.00	.08	.09	.01
" Q	.00	.01	.01	.05	.08	.03
" R	.01	.01	.00	.06	.08	.02
Fine grain panchromatic						
Sample S	+.01	.01	.02	.05	.07	.02
Low shrink base Ss. panchromatic						
Sample T	.00	.02	.02	.10	.11	.01
" U	.01	.02	.01	.10	.11	.01
Nitrate cut film Orthochromatic press						
Sample V	.13	.11	.02	.51	.45	.06
Safety cut film Orthochromatic press						
Sample W	01	.00	.01	.11	.11	.00
Experimental safety cut film						
Sample X	.01	.01	.00	.11	.10	.01

TABLE 5.- PER CENT SHRINKAGE OF ENLARGING PAPERS

Conditioned at 65% R.H., Temperature 70°F.

Type of paper Contrast-surface	Shrinkage		
	Crosswise	Lengthwise	Difference
Single weight regular papers			
Brand E			
Medium	0.27	0.17	0.10
Brand F			
Medium Semi-matte	.41	.27	.14
Brand G			
Medium Semi-matte	.36	.24	.12
" Glossy	.29	.15	.14
" Extra hard	.54	.31	.23
Brand unknown			
Glossy	.30	.28	.02
Double weight regular papers			
Brand H			
Medium Matte	.41	.21	.20
Hard "	.27	.24	.03
Brand I			
Hard	.23	.09	.14
Brand J			
Soft Matte	.45	.17	.28
Normal "	.39	.17	.22
Medium "	.39	.11	.28
Hard "	.43	.16	.27
Extra hard Matte	.41	.15	.26
Brand K			
Medium Semi-gloss	.48	.13	.35
Hard "	.43	.12	.31
Brand L			
Hard Matte	.35	.08	.27
Brand unknown			
Medium Matte	.34	.33	.01
White Rough Matte	.44	.13	.31
Rough Matte	.60	.14	.46
Special aero mapping papers			
Brand W			
Hard Matte	.43	.29	.14
Brand X			
Double weight	.03	.02	.01
Brand Y			
Single weight	.44	.25	.19
Double weight	.18	.16	.02
Metal laminated paper			
Brand Z	.004	+.001	.005

TABLE 4.- PER CENT SHRINKAGE OF CONTACT PAPERS

Conditioned at 65% R.H., Temperature 70°F.

Type of paper	Shrinkage		
	Crosswise	Lengthwise	Difference
Single weight regular papers			
Glossy surfaces			
Brand A			
Extra soft	0.23	0.15	0.08
Normal	.32	.21	.11
Medium	.22	.16	.06
Brand B			
Soft	.42	.02	.40
Normal	.53	.01	.52
Hard	.53	.04	.49
Brand C			
Extra soft	.23	.09	.14
Soft	.19	.17	.02
Normal	.24	.15	.09
Medium	.27	.25	.02
Hard	.23	.11	.12
Extra hard	.26	.20	.06
Brand D			
Soft	.39	.23	.16
Normal	.38	.26	.12
Medium	.41	.29	.12
Hard	.38	.25	.13
Brand unknown	.22	.21	.01
Matte surfaces			
Brand A			
Extra soft	.29	.27	.02
Hard	.21	.16	.05
Double weight regular papers			
Glossy surface			
Brand A			
Normal	.28	.12	.16
Hard	.27	.10	.17
Matte surfaces			
Brand A			
Soft	.34	.14	.20
Normal	.30	.10	.20
Medium	.32	.09	.23
Hard	.28	.12	.16
Extra hard	.35	.07	.28
Brand B			
Normal	.40	.34	.06
Brand unknown			
	.39	.13	.26
	.22	.12	.10
Special aero mapping papers			
Brand X-Double weight	.02	.01	.01
Brand Y-Single weight	.44	.29	.15
Double weight	.13	.12	.01

directions) ranged from .01% to .35%. Four samples had a differential shrinkage of about .45-.50%. Nine samples had a differential shrinkage of .03% or less (exclusive of the three papers mentioned above with low maximum shrinkage)

Summary and Recommendations

This investigation shows that, under controlled conditions, film shrinkage due to processing is quite small. Even with seven days accelerating aging the differential shrinkage is, with one exception, under 0.10%. Comparing the data in Tables 2 and 3 shows that the shrinkage is noticeably smaller at 65% conditioning, in fact the films which had the highest differential shrinkage at 50% show small shrinkage at 65%. This indicates that the best results from an accuracy standpoint could be had if all of the work with films is done in a room conditioned at 65% relative humidity and 72°F. A humidity much above 65% could not be recommended because at the high humidities the behavior of films is erratic.

With photographic papers the results are not so satisfactory. The differential shrinkage is generally above 0.10%. Occasionally very low values were obtained without apparent reason while the same brand, having a different contrast number, is much higher. Another inconsistency is that double-weight papers, as a class, have larger differential shrinkage than single-weight papers. Two of the special air mapping papers gave very low shrinkage and low differential shrinkage. One of these consists of two pieces of waterproofed paper laminated with a sheet of hard aluminum alloy foil, the other is a cellulose lacquered paper.

The hygroscopic nature of film and paper makes it necessary to adopt as standard a fixed condition of temperature and moisture content of the air to which the materials were subjected at the time of testing. In use, these materials are generally handled under uncontrolled conditions, therefore the shrinkage values given in this paper will not be realized in practice.

Undoubtedly, differential shrinkage in paper can be greatly reduced. Since hand-made paper does not have this effect it would seem that paper manufacturers might, after some study, find methods for laying the pulp on the wire to prevent lining up the fibers with the machine direction and for reducing the tension to a minimum on the machine. This is an old problem, the cause is known and the cure should not be too difficult for modern engineers.

We recommend that the machine direction of cut to size film and paper be identified by the manufacturer, either on the package or by printing on the back in the case of paper. If this is done the total differential shrinkage of the combined negative and print or enlargement can be kept at a minimum by having the machine direction of negative and positive material at right angles to each other.

For example:

Machine direction parallel	Shrinkage in percent: Crosswise	Lengthwise	Diff.
Neg.	.42	.27	.15
Pos.	.23	.09	.14
	.65	.35	.29

Machine direction at right angles	Shrinkage in percent: Crosswise	Lengthwise	Diff.
Neg.	.42	.27	.15
Pos.	.09	.23	.14
	.51	.50	.01

Under the recommended conditions the combined differential shrinkage of the positive and negative material would always be less than the value for the material having the greatest differential shrinkage.

It would appear that only nitrate film is used in aerial surveying. Nitrate film is known to be unstable chemically, decomposing spontaneously with time, so that negatives made on this type of base cannot be classed as permanent. In addition, large quantities of nitrate film concentrated in one place, constitute a serious fire hazard with the consequent danger to such official records and personnel as may be in the immediate vicinity. The better grades of cellulose acetate base are much more stable chemically than the nitrate, being in a class with high grade paper from both fire hazard and permanent standpoints. Acetate film is not used in surveying because it is

BELIEVED TO HAVE INFERIOR SHRINKAGE CHARACTERISTICS. WE ARE UNABLE TO FIND ANY RELIABLE DATA ON THIS POINT AND WOULD RECOMMEND THAT A STUDY, SIMILAR TO THAT GIVEN IN THIS REPORT, BE MADE ON ACETATE FILM. CONSIDERING THE LACK OF PERMANENCE AND THE HAZARD IN STORING NITRATE FILM, TOGETHER WITH THE GOOD BEHAVIOR OF TWO SAMPLES OF ACETATE CUT FILM GIVEN IN TABLE 3 (LAST TWO FILMS), IT SEEMS THAT FURTHER ATTENTION TO THIS KIND OF FILM IS WARRANTED.

A NEW STEREOSCOPIC DEVICE
BY DAVID GORDON

AN INTERESTING STEREOSCOPIC DEVICE (U. S. PATENT NO. 1,987,821) WAS DEMONSTRATED IN WASHINGTON RECENTLY. IT CONSISTS OF A SMALL PHOTOGRAPH SUCH AS OBTAINED WITH A MINIATURE CAMERA, HELD CLOSE TO ONE EYE AND VIEWED THROUGH A LENS FOR PROPER FOCUS WHILE THE OTHER EYE VIEWS A NATURAL SCENE OR ANOTHER LARGER PHOTOGRAPH FROM A DIFFERENT VIEWPOINT. THE LARGE AND SMALL PHOTOGRAPHS MUST OF COURSE BE TAKEN FROM DIFFERENT VIEWPOINTS BUT WHEN LENS AND SMALL PHOTOGRAPH ARE PROPERLY ADJUSTED THE IMAGE FROM IT FUSES WITH THE LARGE SCALE VIEW AND STRONG STEREOSCOPIC RELIEF IS OBSERVED.

MANY APPLICATIONS WERE CITED. A SMALL PHOTOGRAPH MAY BE TAKEN AT SOME DISTANCE TO THE RIGHT OF THE CUSTOMARY VIEW OF A SCENE, WHICH WHEN VIEWED THROUGH THE DEVICE WILL STAND OUT IN STRONG STEREOSCOPIC RELIEF. THE DEVICE MAY BE USED FOR PHANTOM EFFECTS. FOR EXAMPLE THE SMALL PHOTO MAY SHOW THE INTERIOR OF A MACHINE AND THE LARGE PHOTO OR DIRECT VIEW ITS EXTERIOR. IN THIS WAY THE OUTSIDE AND INSIDE OF THE MACHINE CAN BE SEEN IN PHANTOM EFFECT AT THE SAME TIME. A CLOSE COMPARISON OF DUPLICATES OF VARIOUS SORTS BY WHICH SMALL DIFFERENCES CAN BE APPRECIATED IS ANOTHER APPLICATION.

MICRO-PHOTOGRAPHS MAY BE VIEWED WITH ONE EYE AND THE OBJECTS THEMSELVES THROUGH THE MICROSCOPE WITH THE OTHER. VERY SLIGHT MOTIONS BECOME PERCEPTIBLE OR BY SHIFTING THE VIEWPOINT THE STEREOSCOPIC RELIEF MAY BE EXAGGERATED AS DESIRED.

THE HILLS AND CRATERS OF THE MOON MAY BE PERCEIVED IN STRONG STEREOSCOPIC RELIEF WHILE LOOKING THROUGH A TELESCOPE WITH ONE EYE AND THE DEVICE WITH A SUITABLE PHOTO WITH THE OTHER.

IT IS INTERESTING THAT THE SMALL PHOTOGRAPH MAY BE THE USUAL BLACK, GRAYS AND WHITE, BUT IF THE LARGE PHOTOGRAPH OR NATURAL SCENE IS IN COLORS, COLORED FUSED IMAGE IN STEREOSCOPIC RELIEF IS PERCEIVED.