1981

The Effects of Testing Temperatures on Elastomeric Impression Materials

Charles J. Wagener
Loyola University Chicago

THE EFFECTS OF TESTING TEMPERATURES ON ELASTOMERIC IMPRESSION MATERIALS

by

Charles J. Wagener

A Thesis Submitted to the Faculty of the Graduate School

of Loyola University of Chicago in Partial Fulfillment

of the Requirements for the Degree of

Master of Science

April

1981

"Man errs, so long as he is striving"

—Goethe

DEDICATION

The labor of this thesis cannot equal the burden endured by my loving wife Joy and my daughter Lisa. So be it, this manuscript represents their endless patience and understanding, and shall forever be a symbol of <u>their</u> dedication.

To Joy and Lisa ——— May your pursuit of knowledge never waver.

ACKNOWLEDGMENTS

I particularly want to express my sincere gratitude to Dr. James L. Sandrik, both friend and advisor, who contributed his enormous energy and talent into making this project a rewarding experience.

Special thanks is due to both Dr. Leon W. Laub and Dr. Joseph M. Gowgiel for their critical review of the text as well as their willingness to offer consultation and suggestions.

I wish to thank Preston Bricker for his expertise in computer technology and his great patience in assisting to organize the voluminous data.

I am indebted to Marge Enyart and Jan Bergman for their unselfish assistance in transcribing this manuscript into a correct and legible format.

I also wish to acknowledge the help of senior photographer James Cockerill, Loyola University School of Dentistry.

My appreciation for their contribution in loaning an oscillating rheometer is extended to the researchers of the Teledyne Dental Products Co., Elk Grove Village, Illinois.

VITA

The author, Charles J. Wagener, is the son of Charles V. Wagener and Corrine (Dahlin) Wagener. He was born on August 7, 1952, in Oak Park, Illinois.

His elementary education was obtained in the public schools of Park Ridge, Illinois and secondary education at Maine Township High School South also in Park Ridge, where he received his diploma in June of 1970.

In September of 1970, he entered Western Illinois University, Macomb, Illinois, where he completed two years of undergraduate study. In September of 1972, he entered Loyola University of Chicago, Lake Shore Campus. In June of 1974, he graduated from Loyola University with a major in biology and received his Bachelor of Science degree.

In September of 1979, after spending 5 years as a sales representative, he entered Loyola University of Chicago Graduate School, Medical Center Campus, Maywood, Illinois. In May of 1981, he graduated with a major in oral biology receiving a Master of Science degree.

Recently, the author has been accepted by the admissions committee of Loyola University School of Dentistry, Maywood, Illinois and plans to enter this graduate program in September of 1981.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

INTRODUCTION

One of the most important industrial reactions of hydrocarbons is the formation of very high molecular weight molecules from relatively simple ones in a process called polymerization. Such is the case with elastomeric impression materials for dental use. The name elastomer, originates from the verbal contraction of elastic polymer, from which it can be implied that these materials harden by polymerization and have rubber-like properties. The rubber industry has coined the word vulcanization (curing) to describe the process of changing a rubber base product, or liquid polymer, to a rubber-like material.

Modern literature describes the synthesis of these materials whereby linear polymers may be joined, or bridged through certain reactive side chains to form three dimensional networks known as cross-linking. The effect of cross-linking on the physical properties varies with the composition and concentration of the cross-linking agent and the polymer system. However, there are certain parameters known to have an influence on the degree and the rate of cross-linking, thus, the achievement of optimal properties. One such parameter that requires attention as a result of recent modifications of testing procedures outlined by the American National Standards Institute/American Dental Association (ANSI/ADA) Specification No. 19 for Non-Aqueous, Elastomeric Impression Materials, is the temperature variable.

The effect of temperature on the testing of elastomeric impression materials was the basis for this investigation.

It was the purpose of this study to attempt to select a testing temperature that accurately reflected clinical conditions, i.e. a practical intraoral temperature. Further to show that 32°C was too low and 37°C too high. This selection was to be made based on the effect of temperature on the degree and rate of polymerization of these materials as measured by determining the degree of permanent deformation and viscosity as a function of time.

In reviewing the literature, it became necessary to discuss this information in three sections. The first part shall deal with the development of the elastomers, secondly, an investigation of test methods and lastly, the influence of temperature.

REVIEW OF THE LITERATURE

One of the early pioneers involved with the research of impression materials was Phillip Pfaff, dentist to Frederick the Great, King of Prussia. Pfaff has been credited with the thought that an ideal impression material would be one which could easily change in form from a plastic state to a rigid material, whereby the details of the oral cavity could be recorded by placing the material in contact with the oral tissues. By obtaining a negative likeness to the tissues involved, a positive reproduction could then be manufactured. In 1756, Pfaff[1] published "Abhandlugg von den Zahnen des menschlichen Korpers und deren Krankheiten", in which he described his technique for the use of wax as an impression material from which a model made of plaster of Paris was used to obtain a hard and rigid copy of the anatomy in question.

The wax, most commonly used for impression taking, was beeswax. Its preparation involved softening the wax in front of a fire and then inserting the material into the mouth without any form of a tray. Various attempts were made to improve the properties of beeswax by combining the wax with other materials, such as shellac or white lead.

It was almost a century later, in the mid-1800's, when Wescott, Dwinelle, and Dunning[2] were credited with the discovery of plaster in specially prepared forms as an impression material.

Thus, the two procedures most widely used during this time involved the making of impressions with either wax or plaster directly, or with plaster in an individual tray of wax.

Then in 1857, a London dentist by the name of Charles Stent, produced the first of a multitude of products to evolve during this period. The impression compound produced by Stent, which still bears his name, could be rendered plastic by heat while having the capability of being re-used almost indefinitely for taking impressions.[1]

A second material, also an impression compound, was introduced by S.S. White in 1874. However, it was not until 1915 when Rupert Hall introduced the correctable modelling plastic-plaster technique, that soon after became a standard for taking impressions.[2]

In 1920 the first truly functional impression waxes were developed. Prior to this period the waxes (paraffin and beeswax) were not only hard and crumbly, but they also flowed much too slowly for taking impressions.

The year 1925 marked the beginning of a new era of impression materials when Alphous Poller[2] of Vienna developed a material capable of registering fine detail, accurately reproducing undercuts, and which could be removed from the oral cavity without fracture or distortion. This new material was described as agar, and later termed reversible hydrocolloid.

During the early 1930's, zinc oxide and eugenol (ZOE) was developed as a multipurpose material. This material could be used as a surgical pack or linings for dentures. It was largely due to the efforts of E.B. Kelly that his material became known as an impression material. Unfortunately, ZOE had some drawbacks as an impression material because in its set condition the material was extremely rigid and brittle, being difficult to use with dentulous patients.[2]

The research that followed these developments led to the discovery of alginate-type materials, and the first American patent was awarded in 1936. It was not until the second World War, when agar products became unavailable for import from Japan, that these materials underwent extensive research. As a result, the first irreversible hydrocolloid (alginate) came into practice, having the ability of reproducing undercuts and fine detail with the added benefit of greater ease of manipulation.[1,2]

In the meantime, the rubber industry was involved in a number of experiments leading to the development of synthetic rubbers. These materials were used by industry for several years before their introduction to the dental profession during the mid-1950's.[3,4] The main constituent of this material is known as a thiokol polysulfide rubber, which stems from a process described by Roydhouse[5] and Braden[6] involving thio-alcohol groups where SH is substituted for OH; hence the name thiokol. The resulting compound is a polyfunctional mercaptan of low molecular weight sold commercially as LP 2 with the average chemical formula of: $HS(R\text{-}S\text{-}S)_{23}\text{-}R\text{-}SH$, where R is: $C_2H_4\text{-}O\text{-}CH_2\text{-}O\text{-}C_2H_4$.

These mercaptan base materials are supplied to the practitioner in the form of a paste contained within two tubes marked base and accelerator (commonly described as catalyst) for easy dispensing. Through chemical analysis of a U.S. product, Skinner[4] has shown the base paste to consist of roughly 80% polysulfide rubber (with terminal mercaptan groups and a limited number of pendant groups), 15% calcium sulfate and 5% zinc oxide. The latter two materials serve as inorganic fillers. The accelerator tube contains 77% lead peroxide as the chain initiator, 3.5% sulfur as a catalyst and filler, and 17% castor oil functioning as a plasticizer to soften the compound. Other accelerators have been $Cu(OH)_2$ or cumene hydroperoxide, which gives a green color to the paste as opposed to the dark brown exhibited by the lead peroxide.[7]

When the two pastes are mixed in the presence of atmospheric moisture, the result is condensation polymerization by oxidation of pendant SH groups, with the formation of water as a by-product. The chemical reaction that occurs has been studied extensively and can be visualized as follows:[3-8]

$$2HS\text{-}(R\text{-}S\text{-}S)_{23}\text{-}R\text{-}SH + PbO_2 \rightarrow$$

$$\text{-}S(R\text{-}S\text{-}S)_{23}\text{-}R\text{-}S\text{-}Pb\text{-}S\text{-}R(S\text{-}S\text{-}R)_{23}\text{-}S\text{-} + 2H_2O.$$

And then followed by:

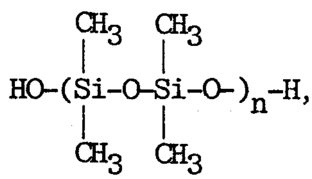
$$\text{-}S(R\text{-}S\text{-}S)_{23}\text{-}R\text{-}S\text{-}Pb\text{-}S\text{-}R(S\text{-}S\text{-}R)_{23}\text{-}S\text{-} + S \rightarrow$$

$$\text{-}S(R\text{-}S\text{-}S)_{23}\text{-}R\text{-}S\text{-}S\text{-}R(S\text{-}S\text{-}R)\text{-}S\text{-} + PbS.$$

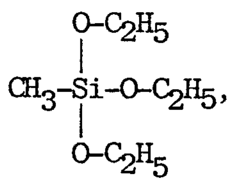
The molecular dimensions and reactivity of these materials permits rapid polymerization to a rubbery solid between oral and room temperature. Braden[6] has stated that "It must be emphasized that cross-linking (via the pendant SH groups) is essential to form an elastic rubber-like material; the chain lengthening via the terminal SH groups is of course necessary to develop optimum physical properties". The final product is extremely inert and will not adhere to paper, glass, acrylic resin, metal, teeth or skin, and has been proven to be a useful dental product.

The silicone rubbers developed as useful impression materials with the introduction of room temperature vulcanized (R.T.V.) silicones.[9] These polymers, which participate in the reaction mechanism, at ambient temperatures, consist of three components:[5,7,9,10]

1. the polymer, a difunctional poly(dimethyl siloxane):



2. the cross-linking agent, either a tri- or tetrafunctional alkyl silicate, such as tri-ethyl silicate:

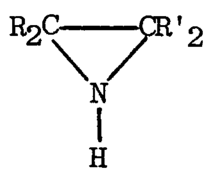


3. and an activator or catalyst, usually an organotin compound like tin octoate:

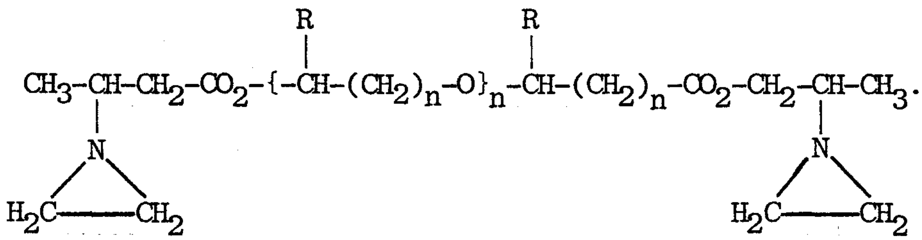
$$Sn(-O_2-C-(CH_2)_6-CH_3)_2.$$

These compounds undergo polymerization spontaneously or under the influence of heat. Formation of the elastomer results from condensation of the terminal hydroxy groups and the ethoxy groups on the orthoethyl silicate, to form a three dimensional network of rubber and the elimination by evaporation of either ethyl or methyl alcohol as a by-product. As a result of the alcohol by-product formation, contraction of the set silicone rubber is likely to occur. The average R.T.V. polymer consists of about 1000 units, which vary in number, site, and direction of cross-links that can be produced. Consequently, a combination of end products of extreme inertness, resistance to oxidation, and thermal stability are available.

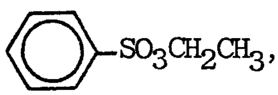
In 1969, Schmitt and co-workers[11] were issued a patent for the development of a new type of elastomeric impression material that could exhibit non-Newtonian, thixotropic behavior. This material is described as a polyether and once again originates in the form of a two paste system. The active ingredient of the base paste involves a low molecular weight polyether molecule with terminal aziridine rings:



The main chain of this polymer has been described as a co-polymer of ethylene oxide and tetrahydrofuran:

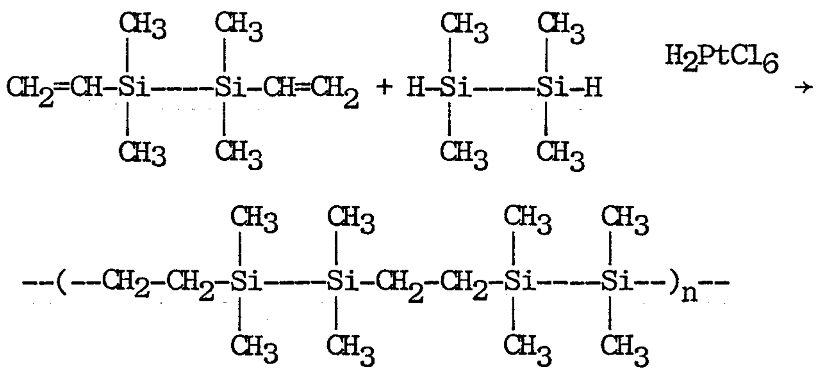


Components of the catalyst paste include an alkyl benzene sulfonate ester serving as a strong acid,



together with a glycol ether plasticizer functioning as a thickening agent. As a result of mixing the two pastes a ring opening mechanism is triggered to allow cross-linking, and is described as a cationic polymerization process, in which the aromatic sulfonate ester serves as a source of cations, producing the set material.[7,9]

The latest development in the field of rubber impression materials stems from a common source located at Wacker-Chemie in Munich, Germany. This is a silicone with a different kind of chemistry in contrast to the conventional or condensation type. This new type of silicone is polymerized by an addition reaction, in which none of the usual volatile by-products are produced from the curing of the impression material. As a result, virtually all the reactants involved will polymerize at oral temperature meaning no shrinkage due to the loss of such substances.[9] The components of this unique material are marketed as a two paste system in collapsible tubes. While one tube contains a low molecular weight silicone with terminal vinyl groups, a reinforcing filler and chloroplatinic acid, the other will consist of a low molecular weight silicone with terminal silane hydrogens and also a reinforcing filler.[7,12] The reaction mechanism is as follows:



The addition of these components during mixing results in a carbon-silicon bond formed between the terminal carbon of the vinyl group and the terminal silane. The polymerization process, involving reduction of the double bond, is aided by the chloroplatinic acid catalyst, and is assumed to be an acid base mechanism as opposed to free radical polymerization.

Throughout the centuries man has developed methods of examining and putting to trial a variety of things in order to ascertain their characteristics. These methods of examination are replenished at a rate often times greater than the development of new test objects, as in the case of dental products, specifically the elastomers.

During their infancy, elastomers were tested[8] by methods described under the A.D.A. Specification No. 11 for Hydrocolloidal Impression Materials-Agar Type, and those methods set forth in Federal Specification U-I-498, Impression Material, Hydrocolloidal, Alginate Type. Since their development for dental use, elastomers have been subjected to a variety of apparatus for determining working and setting time, and elasticity.

In an early study of setting time, Skinner[13] described a modified Vicat needle (needle diameter 3 mm), which was designed to contact the surface of a mixed material within a ring. Penetration determinations were recorded every thirty seconds until a constant minimum reading was attained. Setting time was then defined as the time which elapsed from the beginning of mixing, until the amount of the penetration reached a minimum value of 1 to 2 mm based on 3 to 5 trials.

Miller and others[8], reported a similar test for setting time using a penetrometer with a 1 mm diameter flat-ended needle under a 100 g load. A definite setting time was determined when the penetration was 0.01 of an inch greater than the minimum penetration, based on the average of three readings. In the same study, working time was determined by the use of a penetrometer with a 4 mm diameter flat-ended needle under a 50 g load. After five seconds of needle contact with the specimen, the thickness of the unpenetrated portion of the specimen, below the penetrometer needle, was determined to the nearest 0.001 inch. The time of the last reading, at which the unpenetrated thickness of the specimen was 0.01 inch or less, was considered to be the working time.

The original A.D.A. Specification[14] No. 19 (1966), described yet another needle type penetrometer 2.4 mm in diameter with a flat end weighing 10 g. However, unlike the previous test methods, the working time was recorded as the time elapsed from the start of the mix to the time at which the material fails to string and an indentation persists when the rod is withdrawn.

McLean[15] determined initial setting time with a ¼ lb Gillmore needle, and final setting time with a pointed needle conforming to the specification of the A.S.T.M. D 5-52.

The use of a penetrometer needle offers some disadvantages in view of the fact that it will cover only a limited viscosity range and that it is difficult to obtain many readings on one specimen because of the disturbed surface produced by each penetration. Other variables include size and weight of the needle, time for which the needle is applied, and size of the specimen.[16]

The Revised American National Standards Institute/American Dental Association (ANSI/ADA) Specification No. 19 for Non-Aqueous, Elastomeric Impression Materials[17] described a mold containing six cavities of specified dimension, upon which serially numbered disks are placed on the material at half minute intervals. A required load is applied axially for 15 seconds, after which (depending on the viscosity) the height of each disk is recorded to the nearest 0.02 mm giving reading B. Following reading B, the material is stripped from the mold and the disks returned to their original positions for a second reading A. According to the equation: (B - A = H), the first time H becomes equal or greater than (a) 0.2 mm or (b) twice its value at 1.5 minutes, whichever is greater determines the working time.

It is also of interest to note that the Revised ANSI/ADA Specification No. 19 does not include a test for setting time, but rather defines this period as "the transitional time at which plastic properties which permit molding and impression taking are lost, and elastic properties permitting removal of the impression material over undercuts are acquired".[17]

According to Wilson[18] the rate at which impression materials set is a property of great value in evaluating the suitability of such. The methods described by Anderson,[19] using extrusion viscometry, were found to be inadequate when dealing with materials exhibiting a large rheological change. Herfort,[20] defines rheology as "the study of the flow characteristics of viscous materials".

Flint was first in describing an apparatus used in the rubber industry to determine the curing times of rubber known as a cure-meter. Basically, this instrument involves an electric motor driving an eccentric wheel changing rotary motion to reciprocating motion and then transmitted through a series of linkages to a spring beam.

This beam is connected to a central plate upon which the testing material is placed and a lever is used to produce a deflection pattern recorded on a revolving drum.[18] This apparatus has been further modified by Wilson to accomodate dental materials and described as a reciprocating rheometer. However, the principle remains the same.[16,21]

Based on empirically assessed working times from clinicians, Wilson determined working time to be equivalent to the time when the material was first placed into the instrument and the width of the rheometer trace was 95% of the original trace. Setting time was determined as that time from the start of mix, to the time when the deflection pattern deviates from a curved line and develops a constant deflection pattern.[16] The reciprocating rheometer test for determining the setting characteristics of impression materials exhibits several advantages over previous methods as outlined by Mansfield[22] and Herfort.[20] Some of these advantages include a reproducible measure of setting time, a small amount of material to perform the test and a graphical recording of results.

Cresson[23] investigated elasticity of impression materials by constructing an apparatus to measure permanent deformation by a 12% compressive strain test. The procedure involved cylinders of set material placed within an apparatus consisting of a counterpoised weight system. An applied strain was then delivered by means of a micrometer screw gauge in order to measure permanent deformation.

Fairhurst[3] reported another method of measuring elasticity by the application of a known stress based on A.D.A. Specification No. 11 for testing strain in compression. It should be noted that the test for comparative strain in compression and permanent set used in this study was designed for evaluation of hydrocolloid impression materials for specification purposes.

Jorgensen[24] utilized a spherical indentor to measure elasticity in compression. The indentor was quickly pressed into the impression material and the size of the indentation remaining was obtained by pouring a stone cast, the depth of which was easily measured.

Wilson developed an instrument,[25] described as a balance-beam, capable of applying a given strain. This instrument consists of a horizontal platten connected to a beam by a screw rod, and above the rod a dial gauge to give measurements. The beam is then balanced by means of a weight which upon removal a determined load is applied immediately to the specimen.

Prior to 1967, A.D.A. Specification[14] No. 19, described a standard test, 4.3.6 Permanent deformation, similar to the method developed by Cresson.[23] Since this time, however, the test has been modified and is currently described as 4.3.5 Compression set. According to the Revised ANSI/ADA Specification[17] No. 19, suitable elastic properties are evaluated by a test for compression set. This test measures the ability of a polymerized impression material to recover its original form after being compressed. The intended purpose is to simulate distortion of a polymerized impression during removal and subsequent elastic recovery as it occurs clinically.

After compression of the specimen, the change in height is divided by its initial height and expressed as percentage change. The lower the value for per cent compression set, the greater the elasticity of a given material. In view of the fact that the laboratory test requires a deformation of the specimen, results are dependent upon not only the strain applied, but also the time interval between straining the material and recording the value. According to Wilson,[25] the strain applied clinically is dependent upon the undercut and also upon the thickness of the material involved.

A combination of manipulative and testing variables has been found to greatly influence the physical properties and the clinical success of elastomeric impression materials. Included among these testing parameters is the profound influence of temperature.

In respect to polysulfide elastomers, it has been determined by Jorgensen[24] that the rate of polymerization is approximately doubled with every temperature rise of 10°C, at least between temperatures of 20°C and 70°C. Similarly, Skinner[4] reports that with this type of material, it is not uncommon to find a reduction in working time of 50% or more between a room temperature of 25°C (77°F) and an average oral temperature of 37°C (98.6°F). Braden studied the flow of polysulfide rubbers, at a constant volume rate, through a capillary in the method described as extrusion viscometry.[6,10] As chemical changes occurred within the material that either increased viscosity (polymerization) or promoted an elastic component of deformation (cross-linking), it became necessary to increase the extrusion force to maintain constant volume flow. The extrusion force could then be measured as a function of time. Braden carried this study one step further by examining these characteristics at various testing temperatures in the range of 13.5°C to 37.5°C. Results of this investigation clearly show that the setting process is not independent of testing temperature. As temperatures were decreased from 37.5°C, polymerization and/or cross-linking, as a function of extrusion force, occurs at a significantly slower rate.

Skinner and Cooper[13] investigated the effect of two temperatures, 25°C and 37°C, on the manipulation and setting times of several rubber impression materials. It was concluded that the difference in temperature had a profound effect on both of these times. When the testing temperature was increased to 37°C some elastomers exhibited as much as a 5 minute reduction in setting time. This indicates prolonged setting times at temperatures lower than average (37°C) oral temperature.

Schwindling[26] reported on the effects of setting temperature in terms of shrinkage displayed by some silicone impression materials. Results of this study indicated that the silicone material contracts more rapidly if it sets at temperatures above room temperature.

In final analysis of these findings this investigator concluded, "investigations concerning the practical use of elastomers are useful only if the oral temperature of impression taking is considered".

In a study by Wilson, employing the use of a curemeter[18] to determine setting characteristics, a certain polysulfide material was tested at temperatures of 21°C, 33°C and 37°C, where a 50 per cent reduction in the setting time range with an increase in temperature of 4°C was observed. The setting range was interpreted to be the time period between initial and final set.

In a similar study by Nayyar,[27] comparing the effect of temperature on polysulfide and polyether materials using a rheometer, the data once again bears out the fact that an increase in temperature results in a decrease in the setting range and final setting time. However, it should be noted that the polysulfide material is a great deal more sensitive to temperature than the polyether material, and results indicate that the initial rate of set is more rapid for polyethers than for the polysulfide materials.

Inoue and Wilson[21] studied the effects of temperature on the torsional shear modulus of elastomeric impression materials. The time, t(G = 0.05), at which the modulus attained a value of 0.05 N/mm^2 was chosen since it indicates the time when the rate of polymerization is rapid for three different types of elastomers; the polysulfides, polyethers and silicones. Each of the materials tested were allowed to set at temperatures of 23°C, 32°C and 37°C, after mixing at a room temperature of 23°C. Results from this study once again illustrates the dramatic effect temperature has on the setting characteristics of elastomeric impression materials, especially its influence on the polysulfides as a group. These data led to the conclusion that when testing temperature is increased, a corresponding increase in the rate of polymerization results.

In a study concerning thermal conductivity of silicone base impression materials, Anderson[19] reported that these materials will approximately reach mouth temperature in 3 to 4 minutes when mixed at room temperature (18-20°C).

An investigation by Miller[8] not only revealed a decrease in setting time with an increase in temperature of both polysulfides and silicones, but also the temperature rise above room temperature (22°C) when allowed to set in a simulated oral environment of 37°C. Measurements were made possible by the use of a thermocouple placed in the center of the specimen of specific dimension and the use of 30 gauge wire to minimize heat loss by conduction along the wires. Results indicated that the peak of the temperature rise occured prior to the clinical set of these materials and varies from 3.0°C to 5.2°C.

While many agree that the effects of temperature play a prominent role in determining the physical and mechanical properties, and thus the clinical success of elastomeric impression materials, there seems to be some disagreement concerning the temperature used to simulate oral environment in the laboratory. Although most agree the temperature of the oral cavity to be 37°C ± 1°C, the temperature reached by elastomers setting within the mouth depends upon many factors such as, heat of spatulation, specific heat, heat of reaction and thermal conductivity.

Elborn and Wilson[28] investigated the temperature rise of elastomeric impression materials in the mouth in order to determine the most suitable temperature for testing these materials. Temperatures in this study were measured with copper constantan thermocouples fed into a galvanometer which produced a trace of voltage versus time. The thermocouples were then cemented to trays filled with impression material and placed into two human subjects with oral temperatures of 36°C and 36.6°C respectively.

The data indicates increases in temperature of the elastomer from a mean room status temperature of 19.7°C to a mean oral status temperature of 30.7°C, reflecting an increase of 11°C after 2½ minutes setting time within the mouth. Similarly, the data shows an increase of 11.6°C after 4½ minutes setting to a mean of 31.6°C. Based on these findings Wilson[28] concluded that an average temperature of 32°C simulates, as far as possible, conditions found in clinical practice.

When the Revised ANSI/ADA Specification No. 19, for Non-Aqueous, Elastomeric Impression Materials became effective in 1977, the standard temperature used to simulate oral conditions for testing procedures was adjusted to a lower temperature of 32°C from a previous testing temperature of 37°C. This temperature decrease is reflected in the following physical tests: 4.3.5 Compression set, 4.3.6 Strain in compression, 4.3.7 Detail reproduction, 4.3.8 Compatibility with gypsum and 4.3.10 Metallizing baths, 4.3.9 Dimensional change, and 4.3.12 Flow.

In marked contrast to these developments and the conclusions made by Wilson[28], Sandrik and Sarna[29] have similarly conducted investigations into the temperature of elastomeric impression materials while setting in the mouth. This study gained its impetus from the fact that the time and temperature (32°C) suggested above was found to be insufficient for complete polymerization of elastomeric impression materials currently manufactured in the United States. The end result of testing elastomers at 32°C is permanent deformation caused by the inability of these polymers to elastically respond to the deforming stresses thus, indicating clinical failure. The methods used in this study were similar to the work of Wilson, however, in contrast to using thermocouples which measure temperature differentials to provide a relative measure and having accuracies of ± 1°C or less, Sandrik and Sarna utilized thermistors in their study which provides direct measurement of temperature with an accuracy of ± 0.01°C.

Results of this study indicate that the temperature of all groups (i.e. polysulfide, polyether, conventional and addition silicones) of elastomeric impression materials reached 35.3°C after 4.5 minutes setting time in the mouth, while a temperature of 32°C was attained after 1.6 minutes. The conclusion drawn by these investigators state that certain elastomers are incompletely set when tested at 32°C and allowed to set in the mouth for the period of time recommended by the manufacturer, and that these materials need to be tested at a higher temperature where polymerization will proceed at a faster rate.

Spurred on by the available information contained within this search and controversies that exist on this subject it is the purpose of this investigator to conduct a study to investigate the correct testing temperature for elastomeric impression materials by employing the Revised ANSI/ADA Specification No. 19 test for compression set and utilization of an oscillating rheometer for testing setting time.

MATERIALS AND METHODS

In this investigation seven elastomeric impression materials (Table I) were evaluated: two lead cured polysulfides, one copper cured polysulfide, two condensation silicones, one addition-type silicone, and one polyether. All materials were ordered directly from the manufacturer to insure fresh material and identical batch numbers (Table II).

Laboratory conditions for evaluating these materials were held under strict control to maintain uniform atmospheric conditions of 23 ± 1°C and 50 ± 5% relative humidity. All materials were mixed for a maximum of 45 seconds under these conditions.

In this study two physical tests were conducted in micro-environments (e.g. water bath) at temperatures beginning with 32.0 ± 0.1°C and at 1°C increments through 37.0 ± 0.1°C, for a total of six testing temperatures.

The first physical test used in this study was performed according to the Revised ANSI/ADA Specification No. 19, section 4.3.5, test for compression set, with the exception that in addition to the specified testing temperature of 32.0 ± 1.0°C tests were performed at testing temperatures of 33 ± 0.1°C through 37 ± 0.1°C.

Identical procedures were followed for an additional series of tests on each elastomer with the exception that the manipulation time (i.e. the time in minutes from the start of mix to when the material

TABLE I

Material Name, Generic, Type and

Viscosity per Manufacturer

Name	Generic	Type/Viscosity
Accoe	Condensation silicone	3/Medium
Coe-flex	Polysulfide-Pb cured	1/Medium
Elasticon	Condensation silicone	1/Light
Impregum	Polyether	1/
Omniflex	Polysulfide-Cu cured	1/
Permlastic	Polysulfide-Pb cured	3/Light
Reflect	Addition silicone	1/Medium

TABLE II

Material Name, Manufacturer and Batch Numbers

Name	Manufacturer	Batch Numbers a) carton b) base c) accelerator
Accoe	Coe	a) 071080 A b) 060580 B c) 071080 A
Coe-flex	Coe	a) b) 011180 A c) 050580 B
Elasticon	Kerr	a) 061880 1127 b) 01127 c) 01143
Impregum	Premier/ESPE	a) b) G 176 B c) G 171
Omniflex	Coe	a) 082080 A b) 082080 A c) 072380 C
Permlastic	Kerr	a) 072580 1177 b) 01177 c) 01200
Reflect	Kerr	Compression set a) 011780 1009 b) 01009 c) 01008 Rheometer test a) 080880 1211 b) 01201 c) 01201

is placed in the water bath) was increased from 1.5 minutes to 2.0 minutes with a water bath temperature of 37 ± 0.1°C. This test follows the procedure outlined by A.D.A. Specification No. 19 prior to its revision in 1977.

All materials were proportioned by weight and mixed according to manufacturer's directions (Table III). A sufficient quantity of mixed material was then placed into a lubricated (high vacuum type silicone grease*), split, stainless steel mold (Figure 1).

The mold and material was then placed between two square metal plates separated by two polyethylene sheets. The entire unit is then held tightly by means of a clamp, thus exuding excess material from the mold.

At the designated time from start of mix (1.5 or 2.0 minutes) the entire assembley (Figure 2) of mold, material, polyethylene sheets, metal plates, and clamp was immersed in the water bath** at 32, 33, 34, 35, 36 and 37 ± 0.1°C for the minimum time recommended by the manufacturer (Table III) for removing the impression material from the mouth.

One minute after removal of the specimen from the water bath, a plate weighing 2.5 ± 0.5 g was placed on top of the specimen and together placed in an instrument (Figure 3) consisting of dial gauge

---

* Dow Corning Corporation, Midland, Michigan
** Blue M Electric Company, Blue Island, Illinois

TABLE III

Material Name/Generic, Weight Ratio and

Recommended Time in Mouth

Name/Generic	Weight Ratio (grams) Accelerator/Base	Time (Minutes) In Mouth
Accoe/ Cond. Silicone	1.0/19.0	6.0
Coe-flex/ Polysulfide-Pb	1.0/1.0	8.5
Elasticon/ Cond. Silicone	0.35/15.0 or 1 cc/5.3 g	6.0
Impregum/ Polyether	1.4/10.0	3.0
Omniflex/ Polysulfide-Cu	1.0/2.0	6.0
Permlastic/ Polysulfide-Pb	3.0/2.0	6.0
Reflect/ Add. Silicone	1.0/1.0	4.0

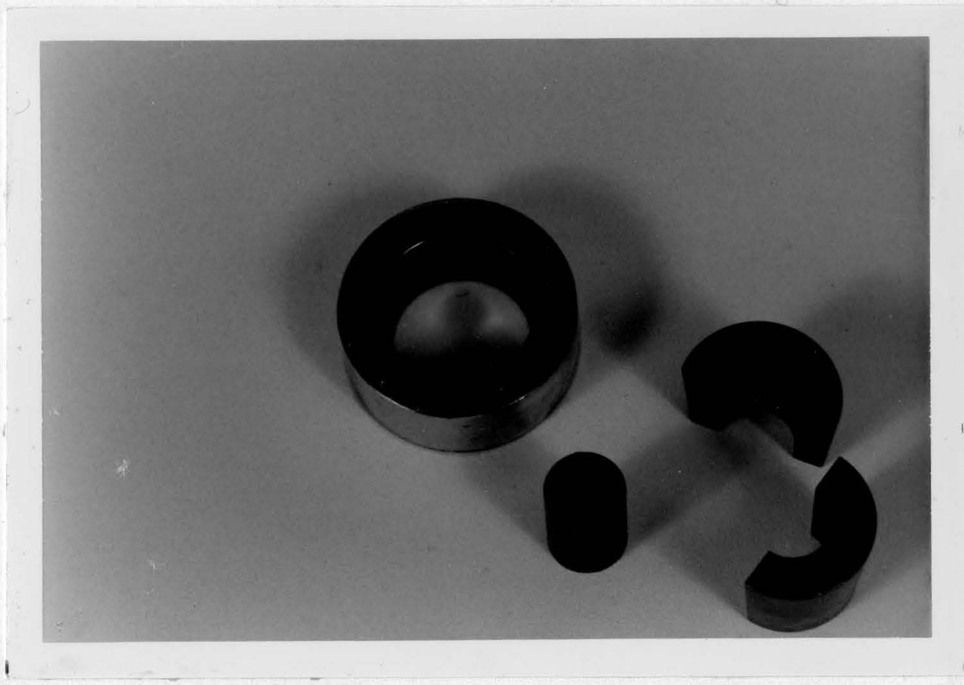


Figure 1. Split stainless steel mold used in making specimens for compression set tests

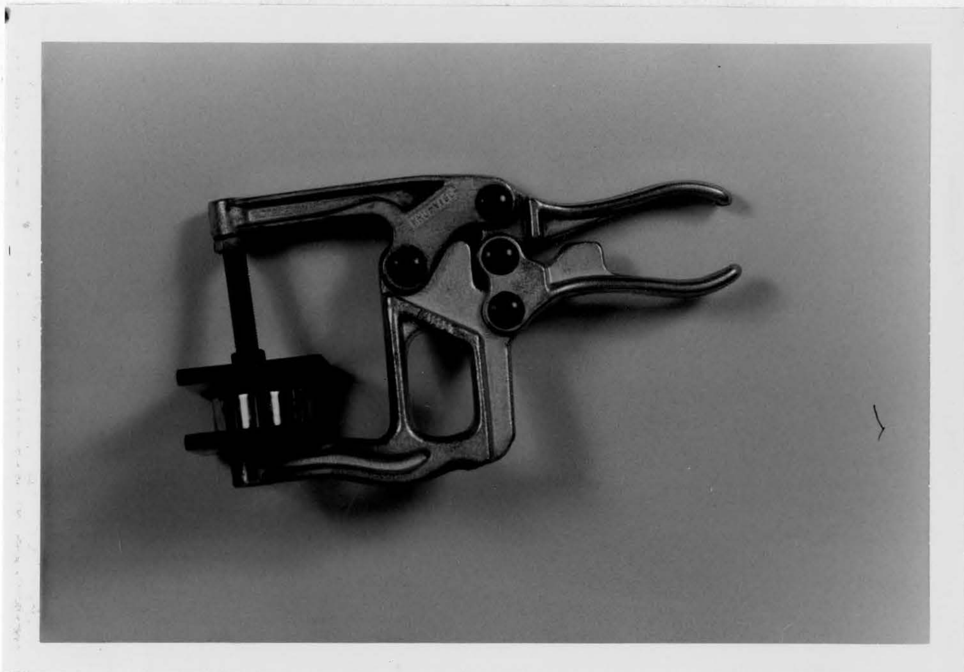


Figure 2. Assembly of mold, polyethylene sheets, metal plates and clamp prepared for water immersion

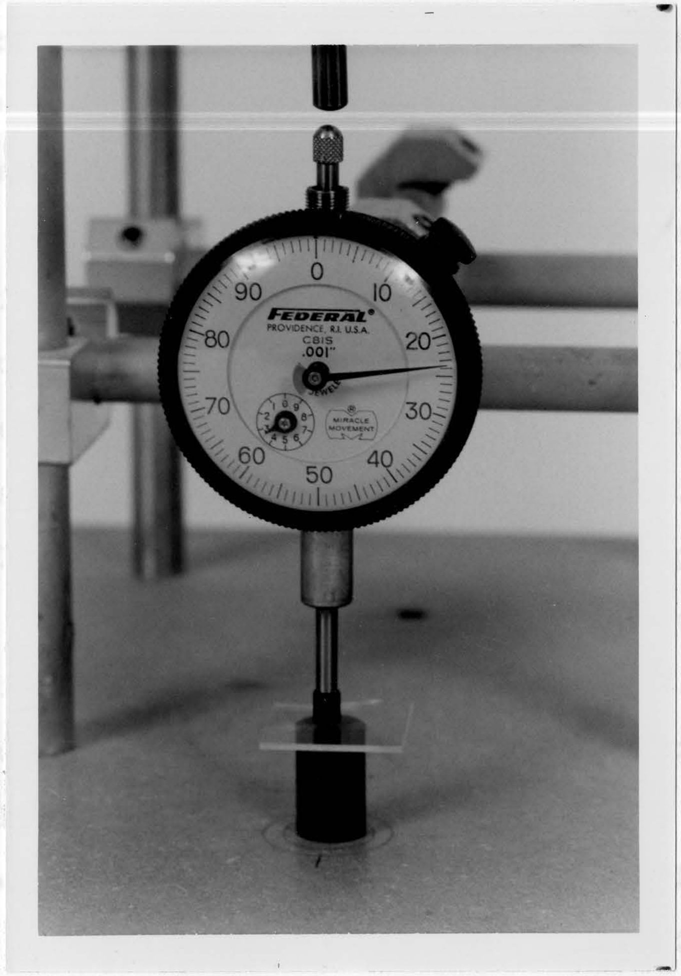


Figure 3. Compression set apparatus

and screw mounted to a steady base. The screw was positioned in such a manner that sufficient force could be applied to the specimen to produce the required amount of strain. The foot of the dial gauge was placed in contact with the plate. The weight of the plate, plus the force of the spring in the gauge, was maintained for 30 seconds, and a value recorded as reading A. The dial gauge foot was then lowered 2.4 mm by means of the screw and maintained for 30 seconds, followed by raising the foot of the dial gauge. The specimen was then allowed to rest under no load except that of the plate for an additional 30 seconds and a second value recorded as reading B. The difference between readings A and B, divided by the original length of the specimen and multiplied by 100, was considered to be the percentage of compression set. The value for compression set was the average of five determinations and was recorded to the nearest 0.01%.

The second physical test was a modification of British Standard No. 4269, part 1, test for working and setting time. The instrument used for this test was a modified oscillating rheometer (Figure 4). This instrument includes two metal plates separated by a 2.5 mm space and sprayed with a dry lubricant releasing agent.* Aside from their purpose of containing the mixed material these metal plates also function to transfer heat from the attached water jackets through which water from a nearby water bath is circulated by means of a pump

---

* Miller-Stephenson Chemical Co., Inc., Chicago, Illinois

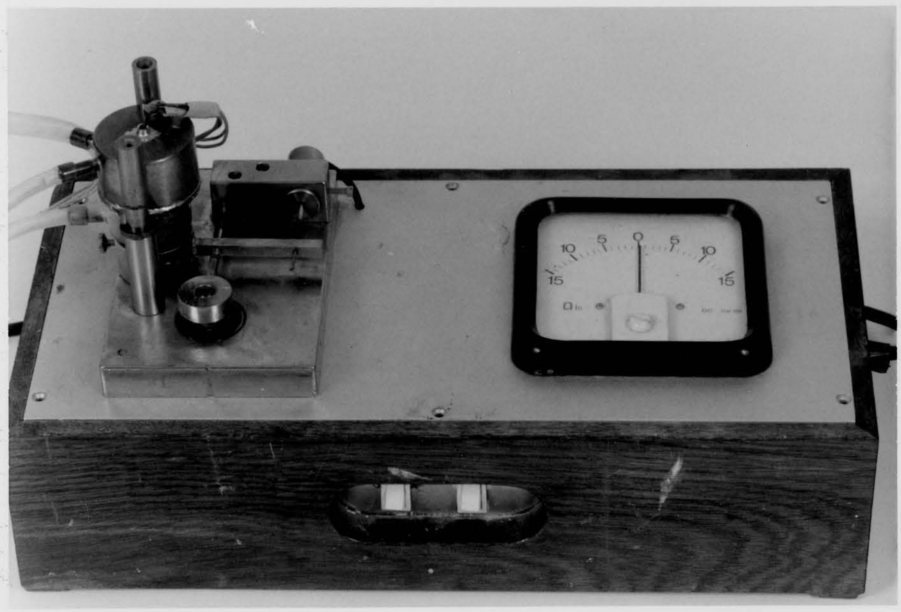


Figure 4. Modified oscillating rheometer

at a rate of 1.4 liters per minute. Two glass probe thermistors (Fenwall GB31P2)* were used to record temperatures; one placed within the upper jacket (Figures 5 & 6) and another placed directly into the setting impression material. The upper plate was mounted stationary by means of thumb nuts while the lower plate oscillates at a rate of 12 times per minute, driven by a small motor mounted beneath the instrument platform. The motor drove an eccentric ball bearing cam, which was attached to the lower plate by two springs. The lower plate moved through a small arc and its movement was transmitted to a linear displacement transducer which converts the movement into an electric signal used to drive the pen of a chart recorder (Figure 7).

All materials were proportioned by weight and mixed according to manufacturer's directions. Approximately 2.5 ml of mixed material was then placed on top of the lower metal plate by means of a syringe at 90 seconds from the start of mix. Within the next 30 seconds the upper plate was mounted in place and at 2.0 minutes from start of mix the rheometer motor was switched on and simultaneously the chart recorder was switched on and recorder pen lowered. Chart speed was set at 2 cm per minute.

A minimum of three recordings were taken for each elastomer at the six designated temperatures for more than a reasonable period of time based on the manufacturer's recommended setting time (Table III).

---

* Fenwal Electronics, Framingham, Massachusets

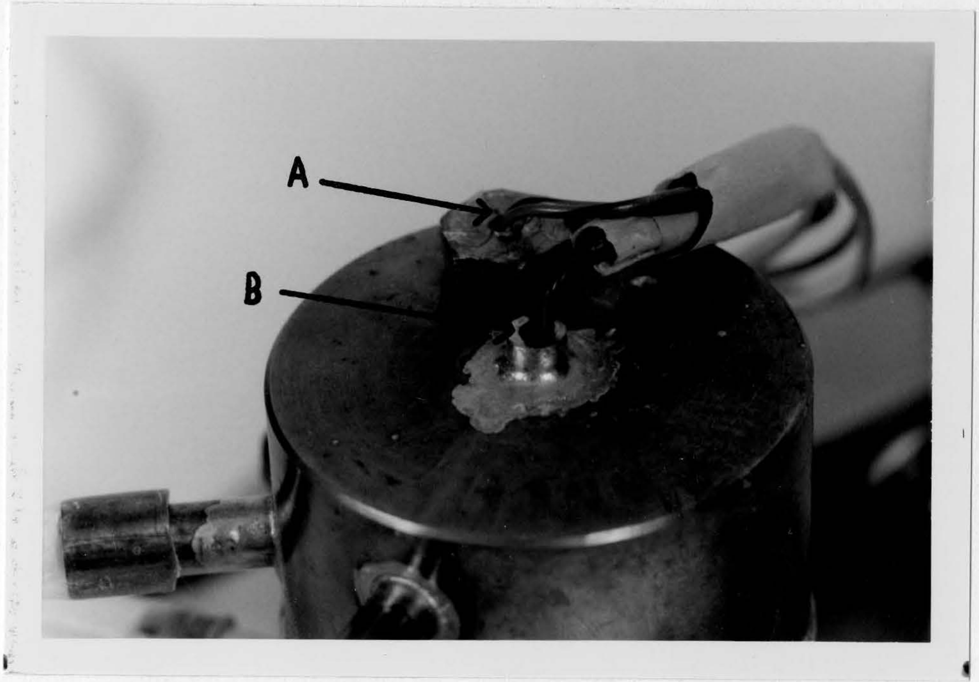


Figure 5. Upper water jacket with wire leads attached to thermistors. Arrow A designates wire leading to thermistor placed within water jacket and arrow B designates wire leading to thermistor that protrudes rheometer plate into the setting material (see Fig. 6)

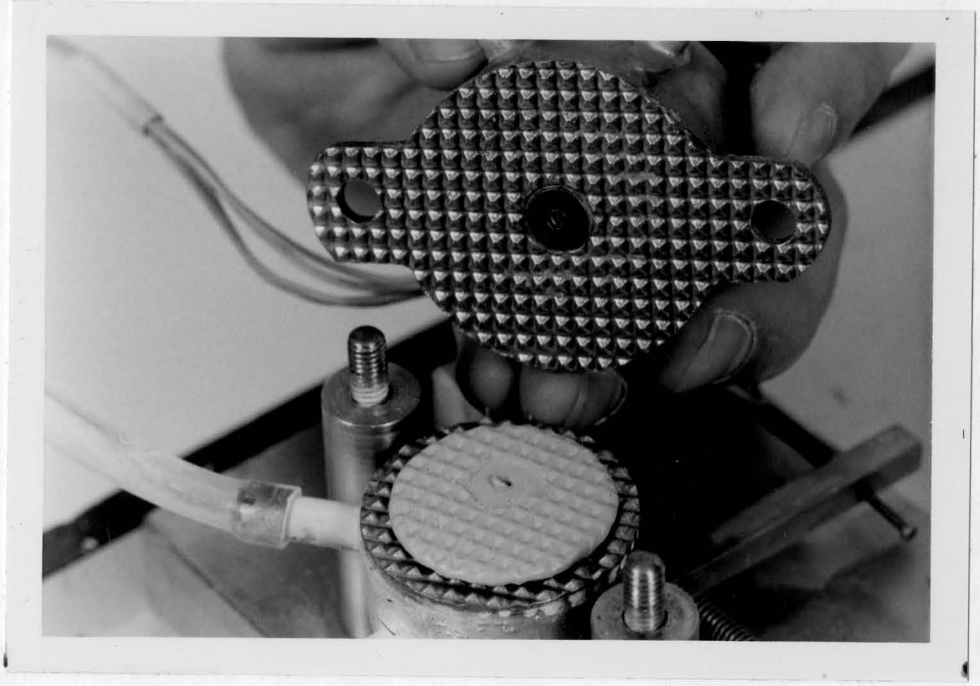


Figure 6. Rheometer plates with view of thermistor

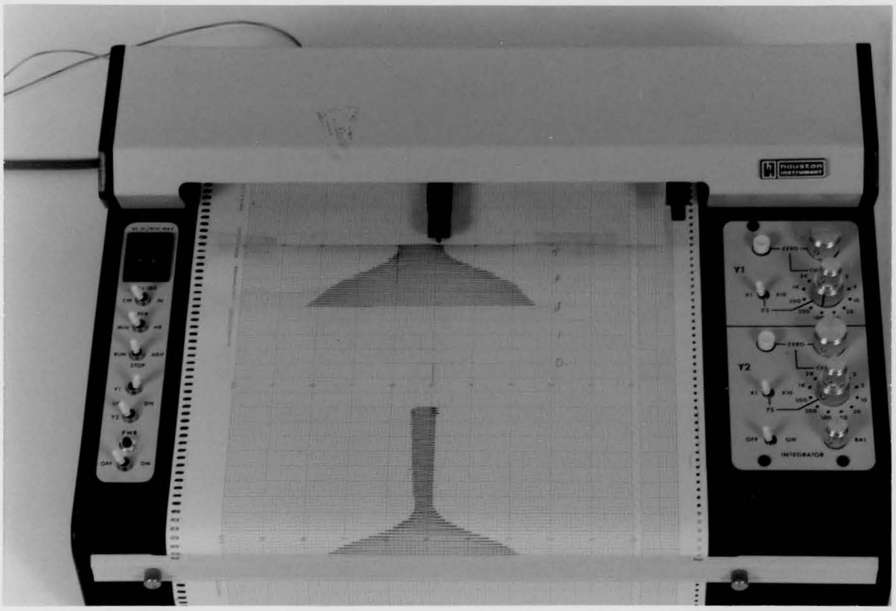


Figure 7. Chart recorder

Two methods were used to evaluate the rheometer tracings. The first of these methods shall be described as the time (minutes) of inflection point. The time (minutes) was derived from the equation: $T = \frac{1}{2}\{t_{(i + 1)} + t_i\}$, or the midpoint of a 15 second time interval when the greatest change (ΔV_{max}, where V = magnitude of deflection) in magnitude of deflection (cm), mathematically represented by the equation: $\Delta V = V(i + 1) - V_i$, occurs. This time (minutes) of inflection point can graphically be displayed by the midpoint between a changing curve from convex to concave. The second method described as setting time is defined as: the time in minutes beyond the inflection point as indicated by the initial point where the magnitude of the deflection pattern decreases by 1 mm or less over a 15 second time interval.

Analysis of the data collected from compression set tests and rheometer traces was determined by statistics for correlation, regression, two sample T-test and one-way analysis of variance. The applied statistics and generation of results were produced by the MINITAB computer program, release 80.1, developed by the Department of Statistics, Pennsylvania State University.

Note: The selection of elastomers for this study were based on their representative type and availability and, in no way reflect any bias on the part of the investigator or manufacturer.

RESULTS

A detailed description of results for each elastomer studied has been prepared in outline form. Along with these results is a graphical representation of each material including a typical rheometer trace shown in Figures 8 through 35. Immediately following this information is a summary of results presented in Tables IV through X. Statistical analysis of results as performed by the Minitab program are included to determine levels of significance.

It was found that the degree of permanent deformation of set impression material was a function of temperature as measured by the ANSI/ADA compression set test, and that certain materials were incompletely set when cured at 32°C. Likewise the setting time as determined by the oscillating rheometer was found to be a function of temperature.

I. Accoe

A. Compression Set Test Results

1. Physical property requirements (part 1a, Revised ANSI/ADA Specification No. 19): based on mean per cent compression set values obtained this material passes the physical property requirement for type 3 material when tested at 32°C and 1°C increments through 37°C. (see Tables IV and V for product comparisons)

2. One-way analysis of variance; compression set (%) vs. temperature (°C): this statistical test indicates that significant ($P < 0.01$) differences in compression set (%) occur between temperatures of 32°C-34°C and 33°C-34°C. (see Table VI for product comparisons)

3. Correlation coefficients (r); compression set (%) vs. temperature (°C): $r = -0.657$. (see table VII for product comparisons)

4. T-test of manipulation times; 1.5 minutes at 37°C vs. 2.0 minutes at 37°C: this statistical test indicates that significant differences ($P < 0.05$) in compression set (%) occur between manipulation times of 1.5 minutes at 37°C and 2.0 minutes at 37°C. (see Table VIII for product comparisons)

B. Rheological Test Results

1. Inflection point times and setting times are found in Tables IX and X respectively, and Figure 8 shows a typical rheometer trace for this product.
2. Correlation coefficient (r); inflection point time (minutes) vs. temperature (°C): r = -0.887. (see Table VII for product comparisons)
3. Correlation coefficient (r); setting time (minutes) vs. temperature (°C): r = -0.949. (see Table VII for product comparisons)
4. Correlation coefficient (r); setting time (minutes) vs. inflection point time (minutes): r = +0.766. (see Table VII for product comparisons)

C. Regression Equations (y = mx + b)

1. Compression set (%) vs. temperature (°C): y = -0.111x + 4.82. (graphically shown in Fig. 9)
2. Inflection point time (minutes) vs. temperature (°C): y = -0.115x + 7.34. (graphically shown in Fig. 10)
3. Setting time (minutes) vs. temperature (°C): y = -0.265x + 15.0. (graphically shown in Fig. 11)
4. Setting time (minutes) vs. inflection point time (minutes): y = 1.112x + 4.168.

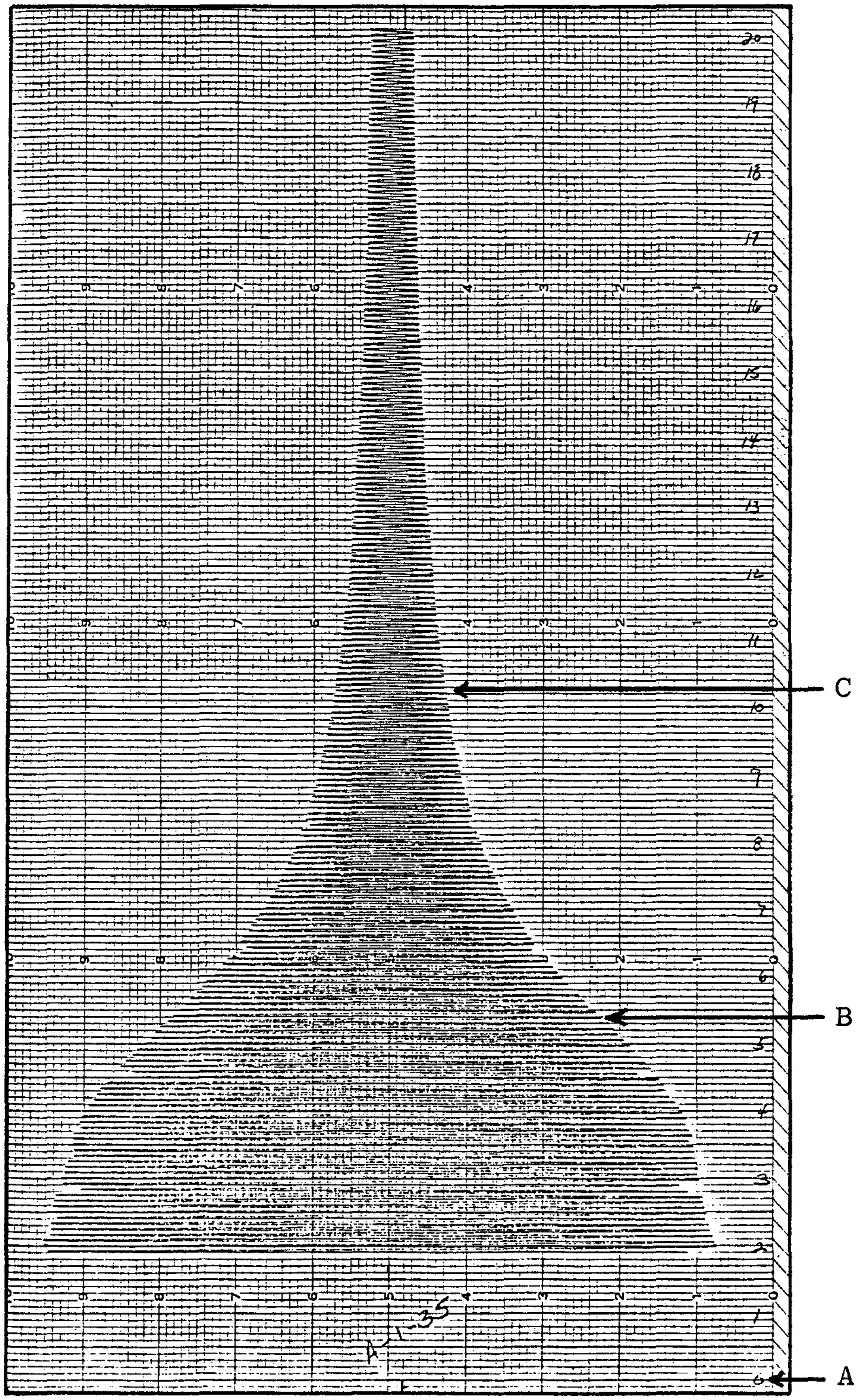


Figure 8. Accoe: Typical Rheometer Trace (35°C)

A: Start of Mix .... 0.00 min.
B: Inflection Point Time ... 5.38 min.
C: Setting Time .... 10.25 min.

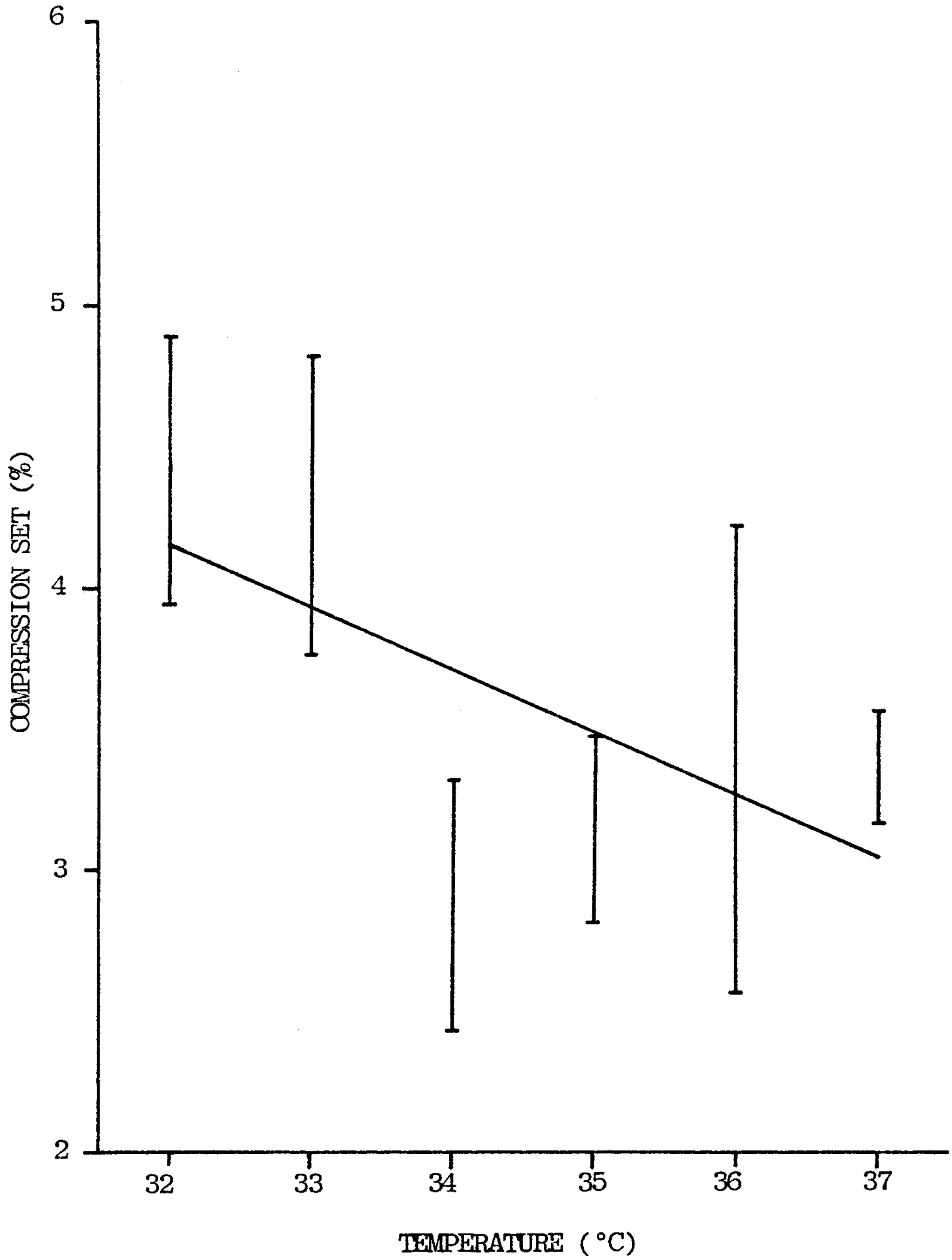


Figure 9. Compression set vs. temperature data including regression line for Accoe silicone impression material. (r = -0.657)

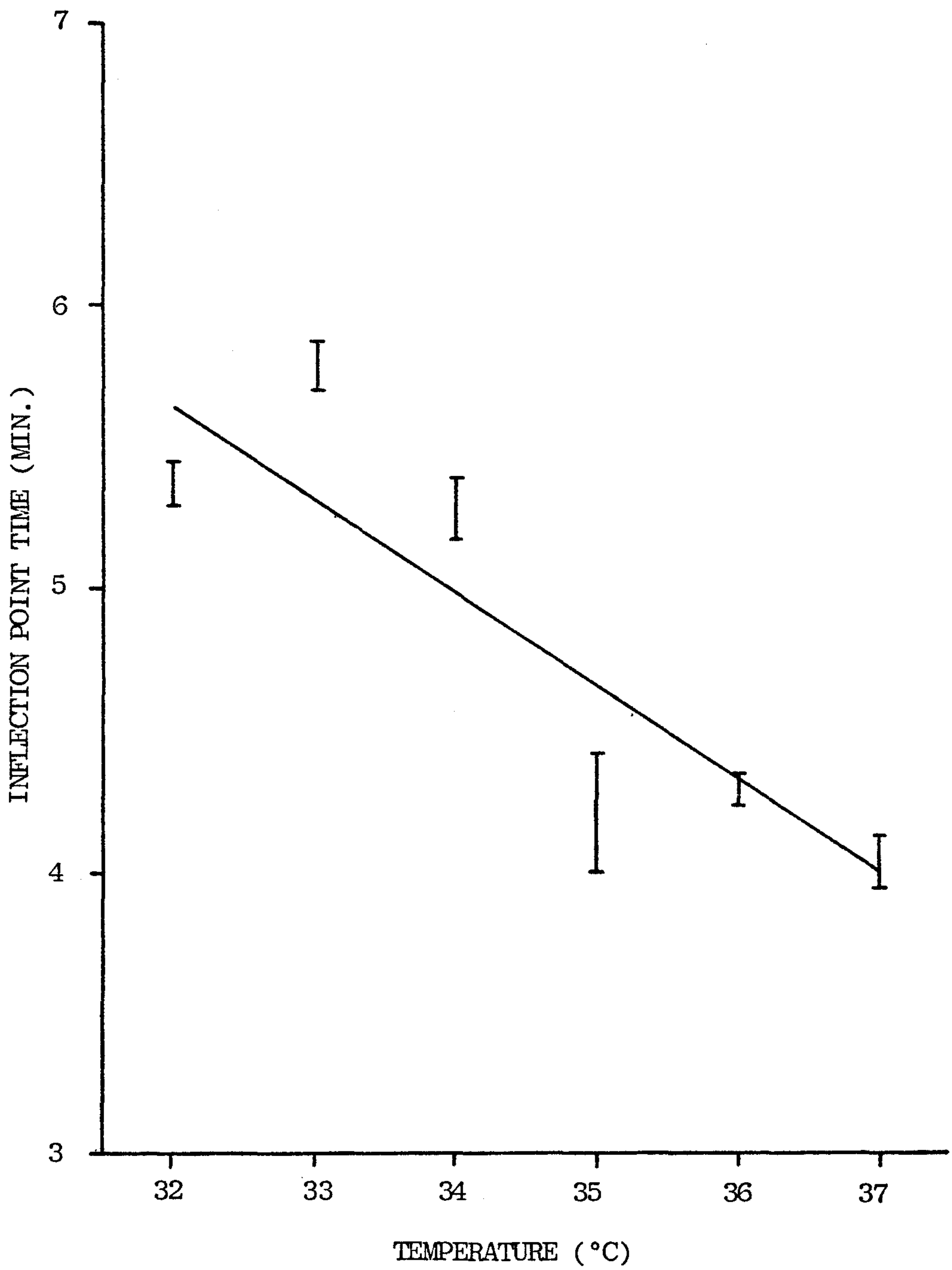


Figure 10. Inflection point time vs. temperature data including regression line for Accoe silicone impression material. (r = -0.887)

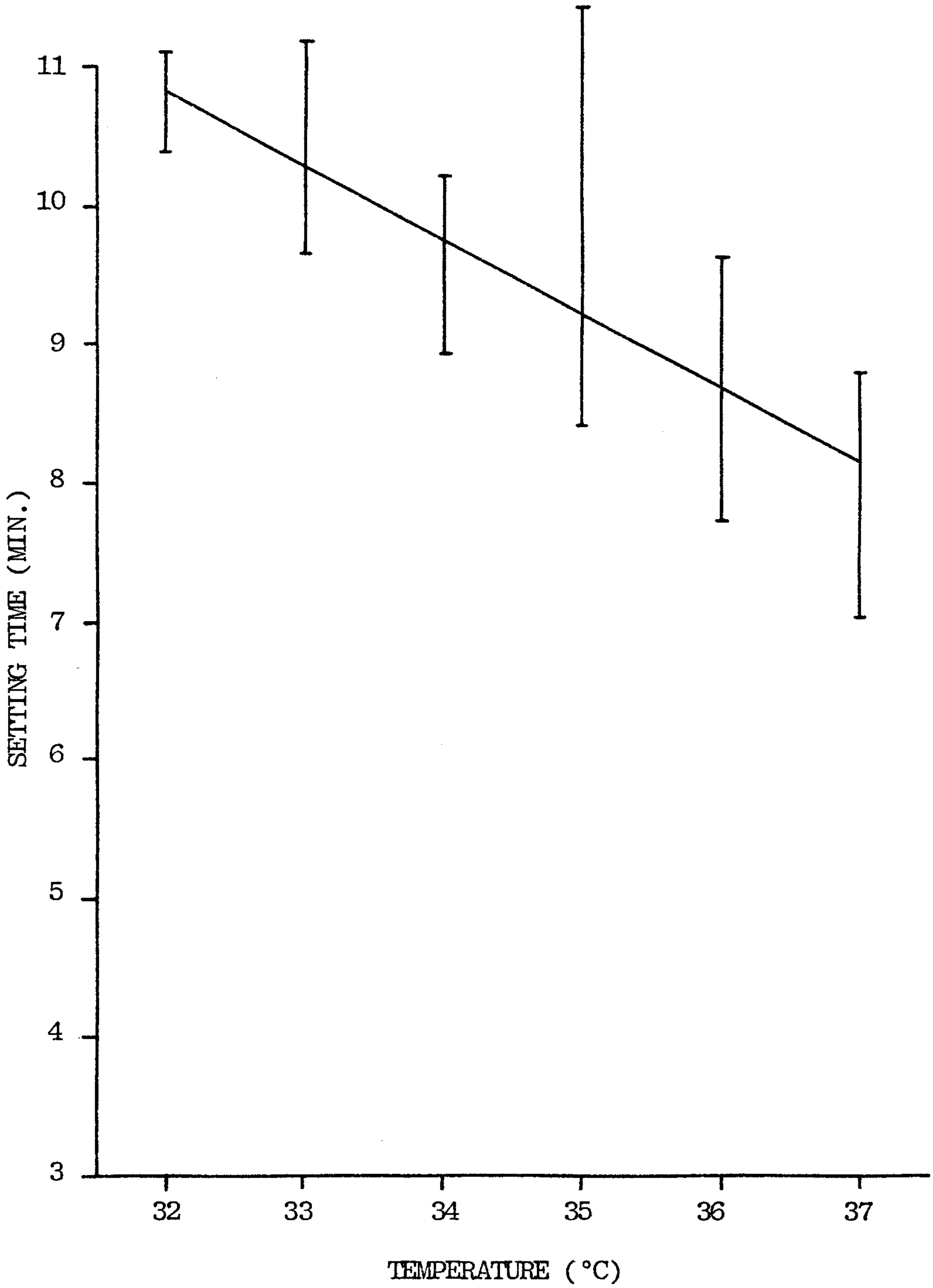


Figure 11. Setting time vs. temperature data including regression line for Accoe silicone impression material. (r = -0.949)

II. Coe-flex

A. Compression Set Test Results

1. Physical property requirements (part 1a, Revised ANSI/ADA Specification No. 19): based on mean per cent compression set values obtained this material fails physical property requirement for type 1 material when tested at a temperature of 32°C and 1°C increments through 37°C. (see Tables IV and V for product comparisons)

2. One-way analysis of variance; compression set (%) vs. temperature (°C): this statistical test indicates that significant ($P < 0.01$) differences in compression set (%) occur between temperatures of 32°C-33°C, 33°C-34°C, 34°C-35°C and 35°C-36°C. (see Table VI for product comparisons)

3. Correlation coefficients (r); compression set (%) vs. temperature (°C): $r = -0.989$. (see Table VII for product comparisons)

4. T-test of manipulation times; 1.5 minutes at 37°C vs. 2.0 minutes at 37°C: this statistical test indicates that no significant differences ($P < 0.05$) in compression set (%) occur between manipulation times of 1.5 minutes at 37°C and 2.0 minutes at 37°C. (see Table VIII for product comparisons)

B. Rheological Test Results

1. Inflection point times and setting times are found in Tables IX and X respectively, and Figure 12 shows a typical rheometer trace for this product.

2. Correlation coefficient (r); inflection point time (minutes) vs. temperature (°C): $r = -0.828$. (see Table VII for product comparisons)

3. Correlation coefficient (r); setting time (minutes) vs. temperature (°C): $r = -0.979$. (see Table VII for product comparisons)

4. Correlation coefficient (r); setting time (minutes) vs. inflection point time (minutes): $r = +0.896$. (see Table VII for product comparisons)

C. Regression Equations ($y = mx + b$)

1. Compression set (%) vs. temperature (°C): $y = -0.375x + 16.5$. (graphically shown in Fig. 13)

2. Inflection point time (minutes) vs. temperature (°C): $y = -0.271x + 13.4$. (graphically shown in Fig. 14)

3. Setting time (minutes) vs. temperature (°C): $y = -0.443x + 22.4$. (graphically shown in Fig. 15)

4. Setting time (minutes) vs. inflection point time (minutes): $y = +1.232x + 2.164$.

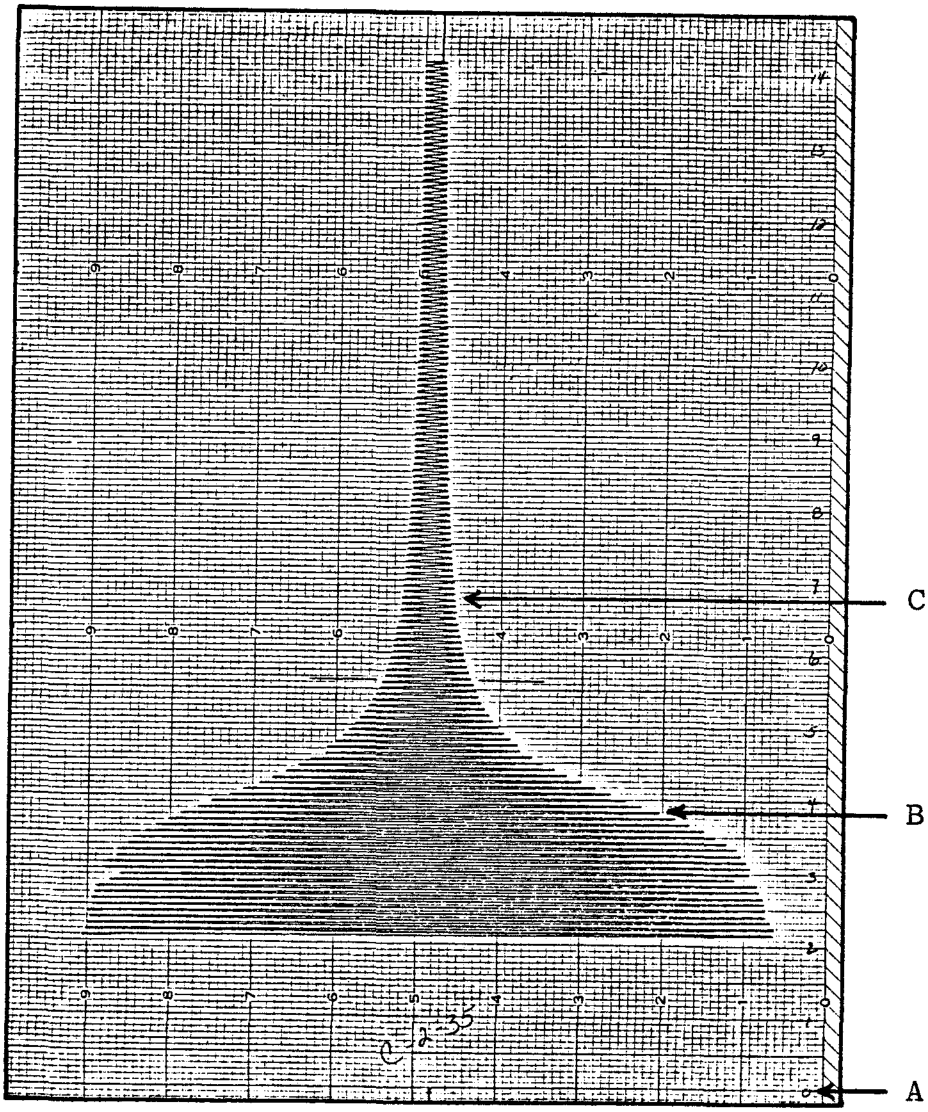


Figure 12. Coe-flex: Typical Rheometer Trace (35°C)

A:	Start of Mix	0.00 min.
B:	Inflection Point Time	3.88 min.
C:	Setting Time	6.75 min.

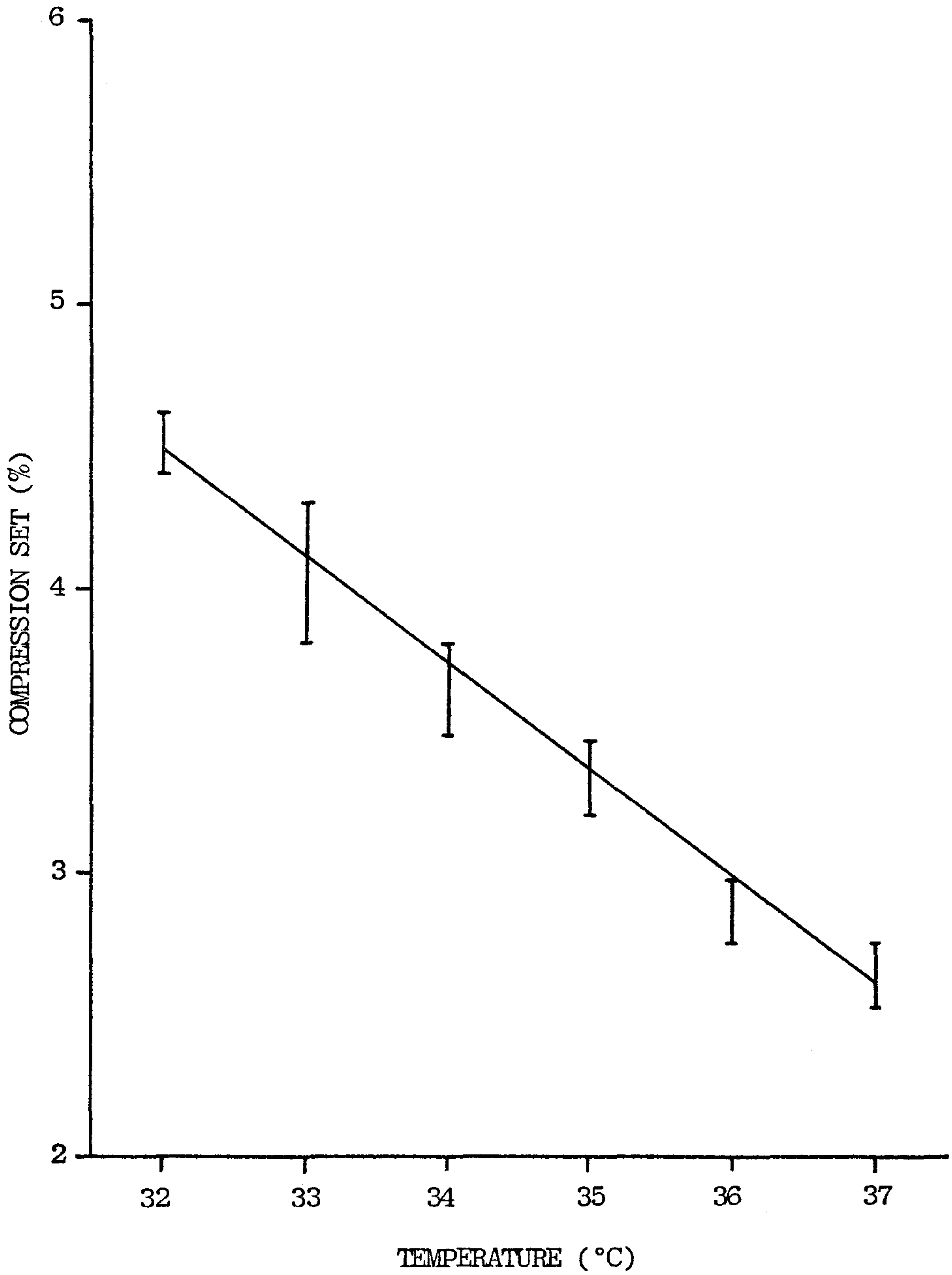


Figure 13. Compression set vs. temperature data including regression line for Coe-flex polysulfide impression material. (r = −0.989)

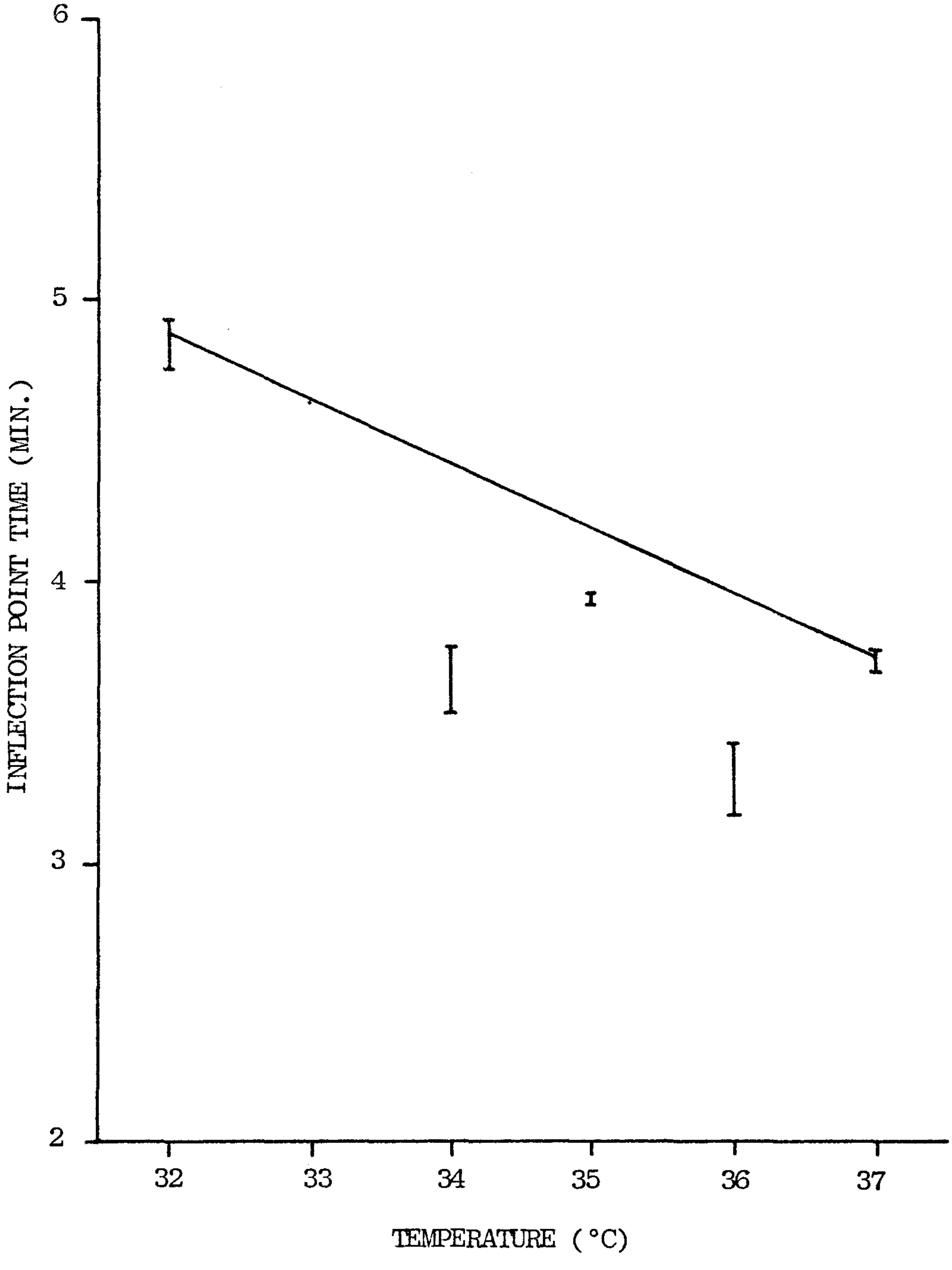


Figure 14. Inflection point time vs. temperature data including regression line for Coe-flex polysulfide impression material. (r = -0.828)

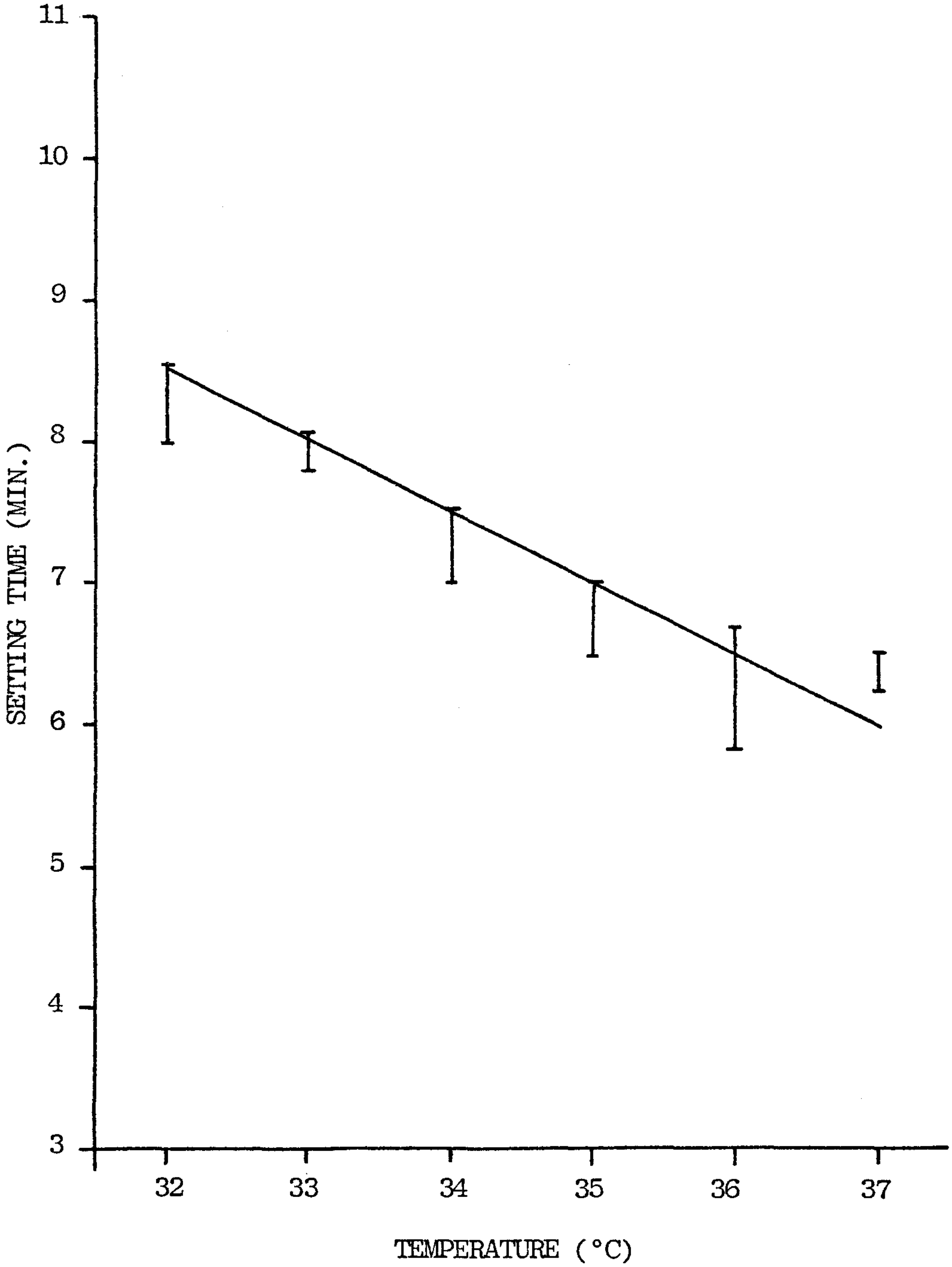


Figure 15. Setting time vs. temperature data including regression line for Coe-flex polysulfide impression material. (r = -0.979)

III. Elasticon

A. Compression Set Test Results

1. Physical property requirements (part 1a, Revised ANSI/ADA Specification No. 19): based on mean per cent compression set values obtained this material passes the physical property requirement part 1a for type 1 material when tested at 32°C and 1°C increments through 37°C. (see Tables IV and V for product comparisons)

2. One-way analysis of variance; compression set (%) vs. temperature (°C): this statistical test indicates that significant ($P < 0.01$) differences in compression set (%) occur between temperatures of 32°C-33°C, 33°C-35°C and 34°C-36°C. (see Table VI for product comparisons)

3. Correlation coefficients (r); compression set (%) vs. temperature (°C): $r = -0.968$. (see Table VII for product comparisons)

4. T-test of manipulation time; 1.5 minutes at 37°C vs. 2.0 minutes at 37°C: this statistical test indicates that significant differences ($P < 0.05$) in compression set (%) occur between manipulation times of 1.5 minutes at 37°C and 2.0 minutes at 37°C. (see Table VIII for product comparisons)

B. Rheological Test Results

1. Inflection point times and setting times are found in Tables IX and X respectively, and Figure 16 shows a typical rheometer trace for this product.
2. Correlation coefficient (r); inflection point time (minutes) vs. temperature (°C): $r = -0.906$. (see Table VII for product comparisons)
3. Correlation coefficient (r); setting time (minutes) vs. temperature (°C): $r = -0.898$. (see Table VII for product comparisons)
4. Correlation coefficient (r); setting time (minutes) vs. inflection point time (minutes): $r = +0.855$. (see Table VII for product comparisons)

C. Regression Equations ($y = mx + b$)

1. Compression set (%) vs. temperature (°C): $y = -0.223x + 11.3$. (graphically shown in Fig. 17)
2. Inflection point time (minutes) vs. temperature (°C): $y = -0.336x + 16.4$. (graphically shown in Fig. 18)
3. Setting time (minutes) vs. temperature (°C): $y = -0.539x + 28.1$. (graphically shown in Fig. 19)
4. Setting time (minutes) vs. inflection point time (minutes): $y = +1.993x + -0.836$.

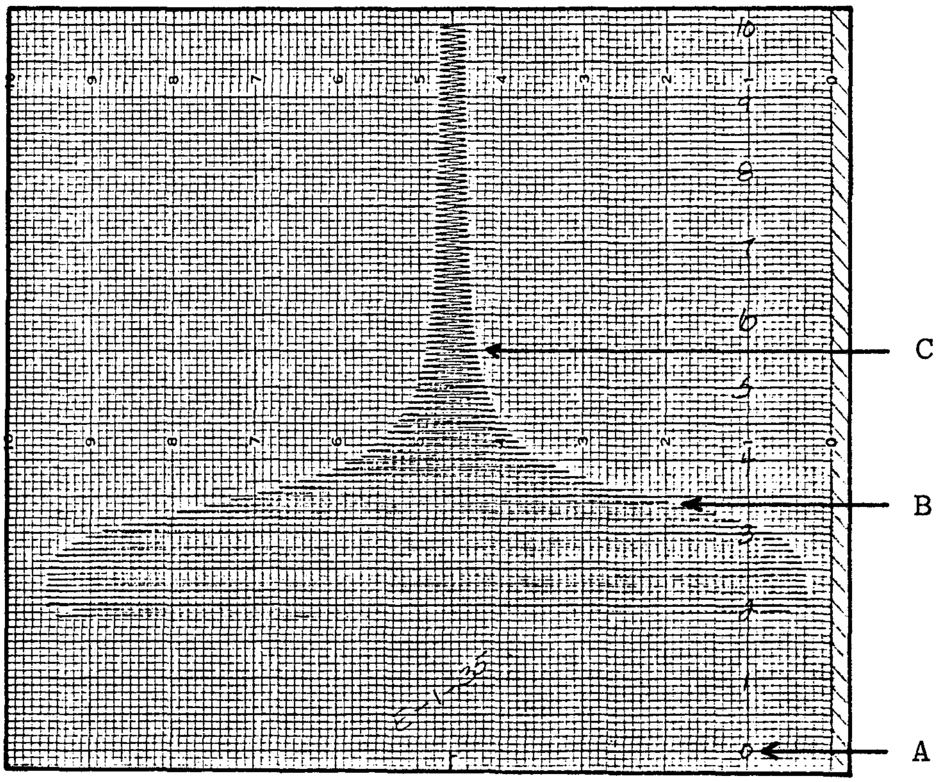


Figure 16. Elasticon: Typical Rheometer Trace (35°C)

A:	Start of Mix	0.00 min.
B:	Inflection Point Time ...	3.38 min.
C:	Setting Time	5.50 min.

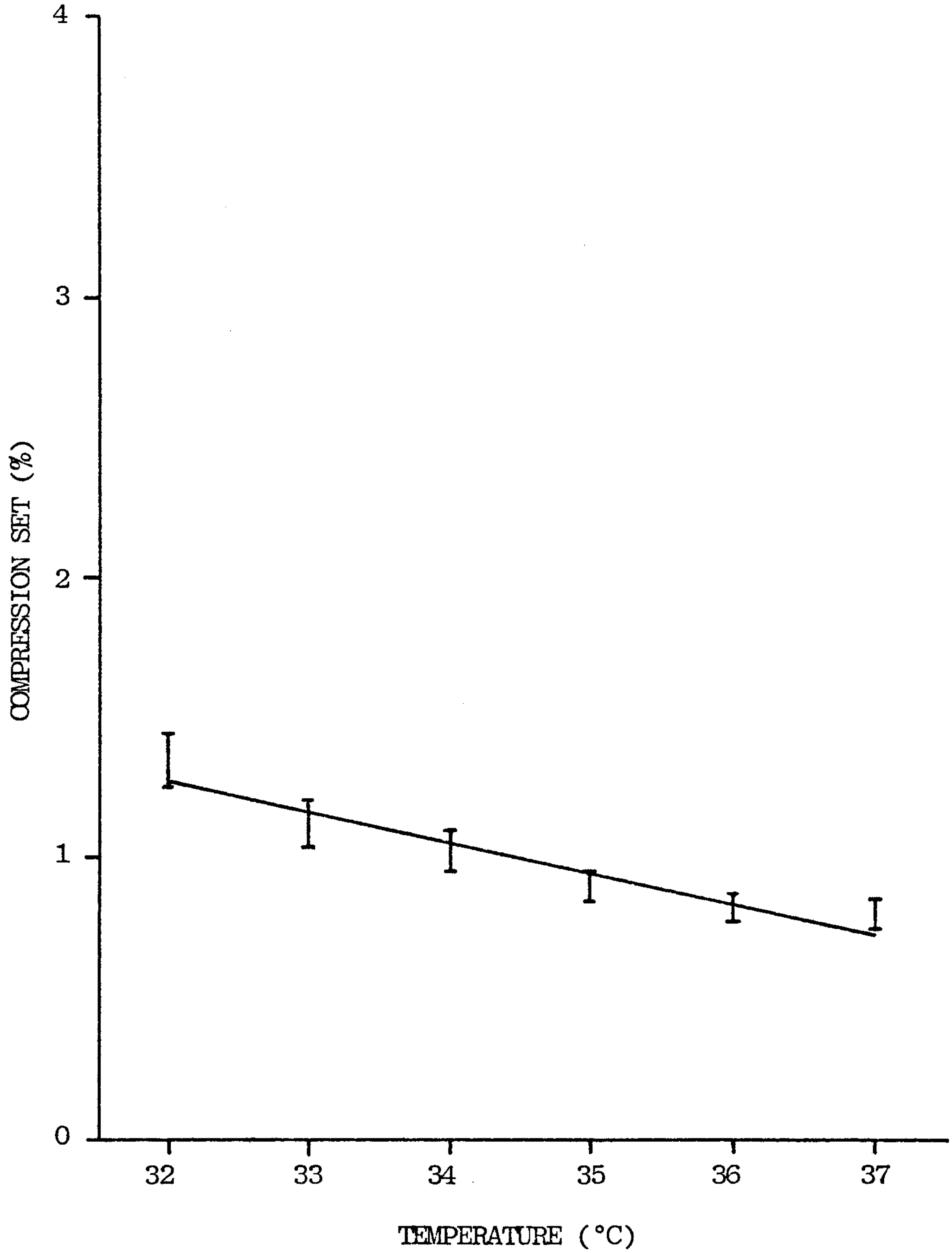


Figure 17. Compression set vs. temperature data including regression line for Elasticon silicone impression material. (r = -0.968)

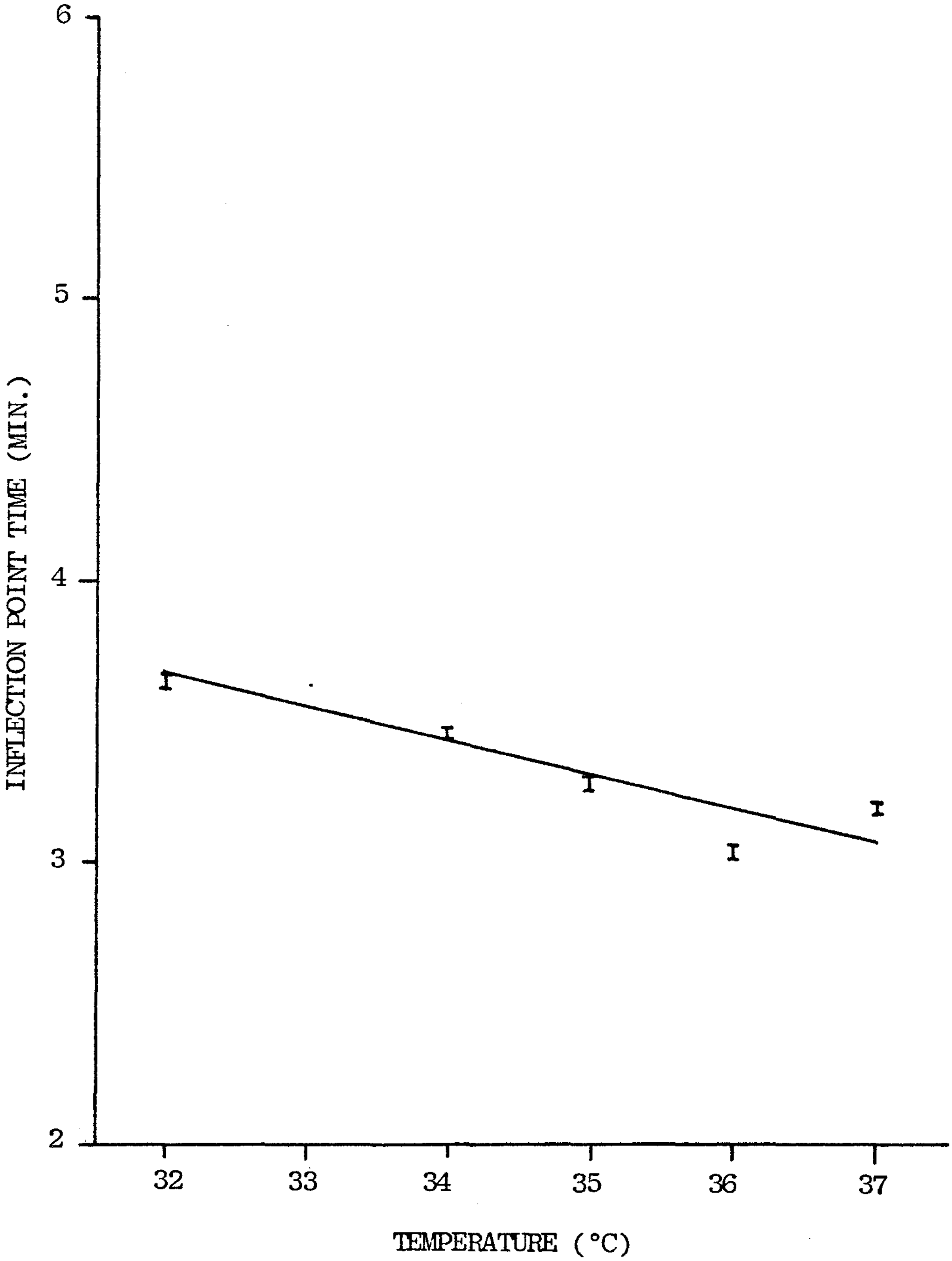


Figure 18. Inflection point time vs. temperature data including regression line for Elasticon silicone impression material. ($r = -0.906$)

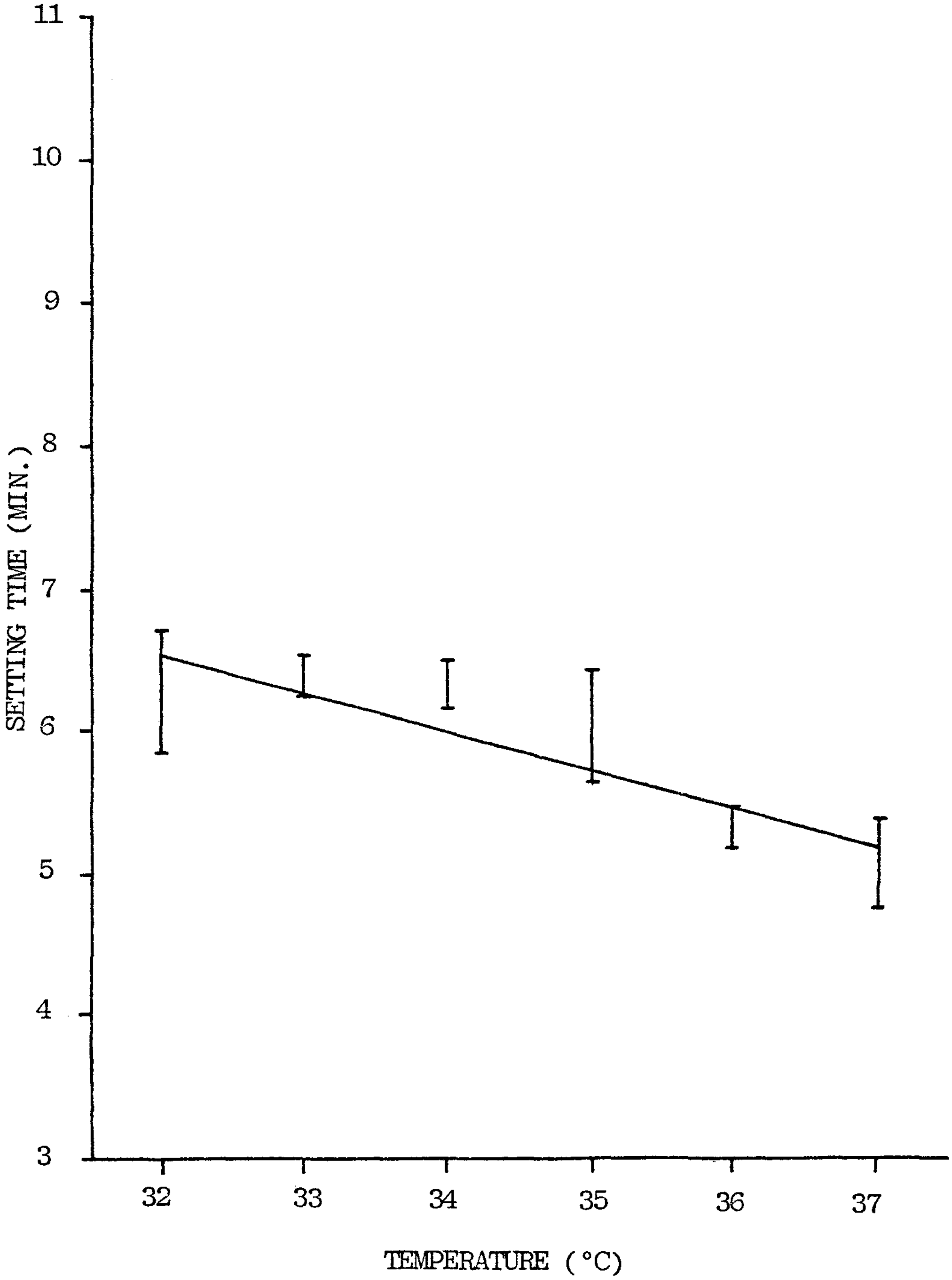


Figure 19. Setting time vs. temperature data including regression line for Elasticon silicone impression material. (r = -0.898)

IV. Impregum

A. Compression Set Test Results

1. Physical property requirements (part 1a, Revised ANSI/ADA Specification No. 19): based on mean per cent compression set values obtained this material passes the physical property requirement for type 1 material when tested at 32°C and 1°C increments through 37°C. (see Tables IV and V for product comparisons)

2. One-way analysis of variance; compression set (%) vs. temperature (°C): this statistical test indicates that no significant ($P < 0.01$) differences in compression set (%) occur between temperatures of 32°C through 37°C. (see Table VI for product comparisons)

3. Correlation coefficients (r); compression set (%) vs. temperature (C): $r = -0.413$. (see Table VII for product comparisons)

4. T-test of manipulation times; 1.5 minutes at 37°C vs. 2.0 minutes at 37°C: this statistical test indicates that no significant differences ($P < 0.05$) in compression set (%) occur between manipulation times of 1.5 minutes at 37°C and 2.0 minutes at 37°C. (see Table VIII for product comparisons)

B. Rheological Test Results

1. Inflection point times and setting times are found in Tables IX and X respectively, and Figure 20 shows a typical rheometer trace for this product.
2. Correlation coefficient (r); inflection point time (minutes) vs. temperature (°C): r = -0.427. (see Table VII for product comparisons)
3. Correlation coefficient (r); setting time (minutes) vs. temperature (°C): r = -0.269. (see Table VII for product comparisons)
4. Correlation coefficient (r); setting time (minutes) vs. inflection point time (minutes): r = +0.871. (see Table VII for product comparisons)

C. Regression Equations (y = mx + b)

1. Compression set (%) vs. temperature (°C): y = -0.0334x + 3.51. (graphically shown in Fig. 21)
2. Inflection point time (minutes) vs. temperature (°C): y = -0.0286x + 3.5. (graphically shown in Fig. 22)
3. Setting time (minutes) vs. temperature (°C): y = -0.0381x + 5.81. (graphically shown in Fig. 23)
4. Setting time (minutes) vs. inflection point time (minutes): y = +1.878x + -0.227.

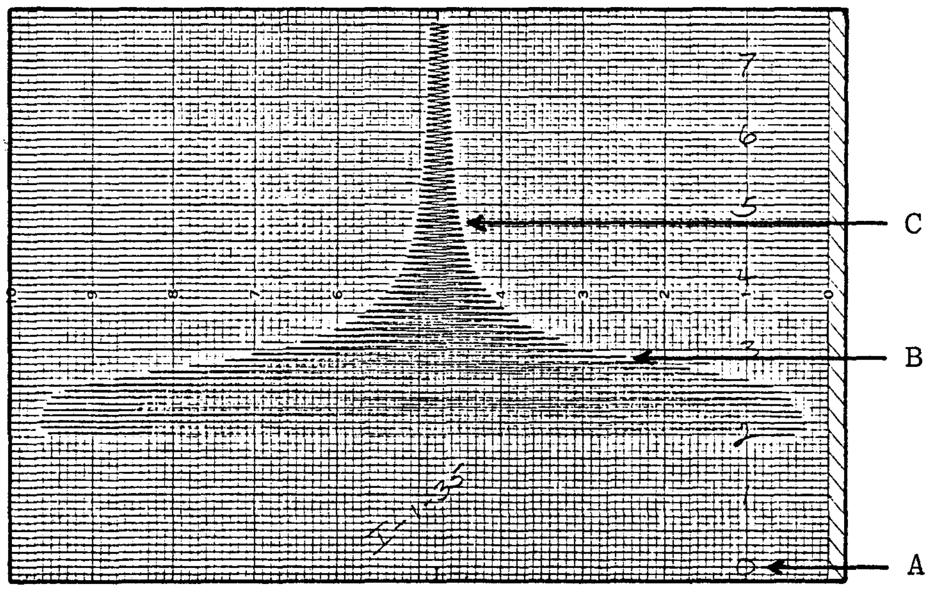


Figure 20. Impregum: Typical Rheometer Trace (35°C)

A:	Start of Mix	0.00 min.
B:	Inflection Point Time ...	2.88 min.
C:	Setting Time	4.75 min.

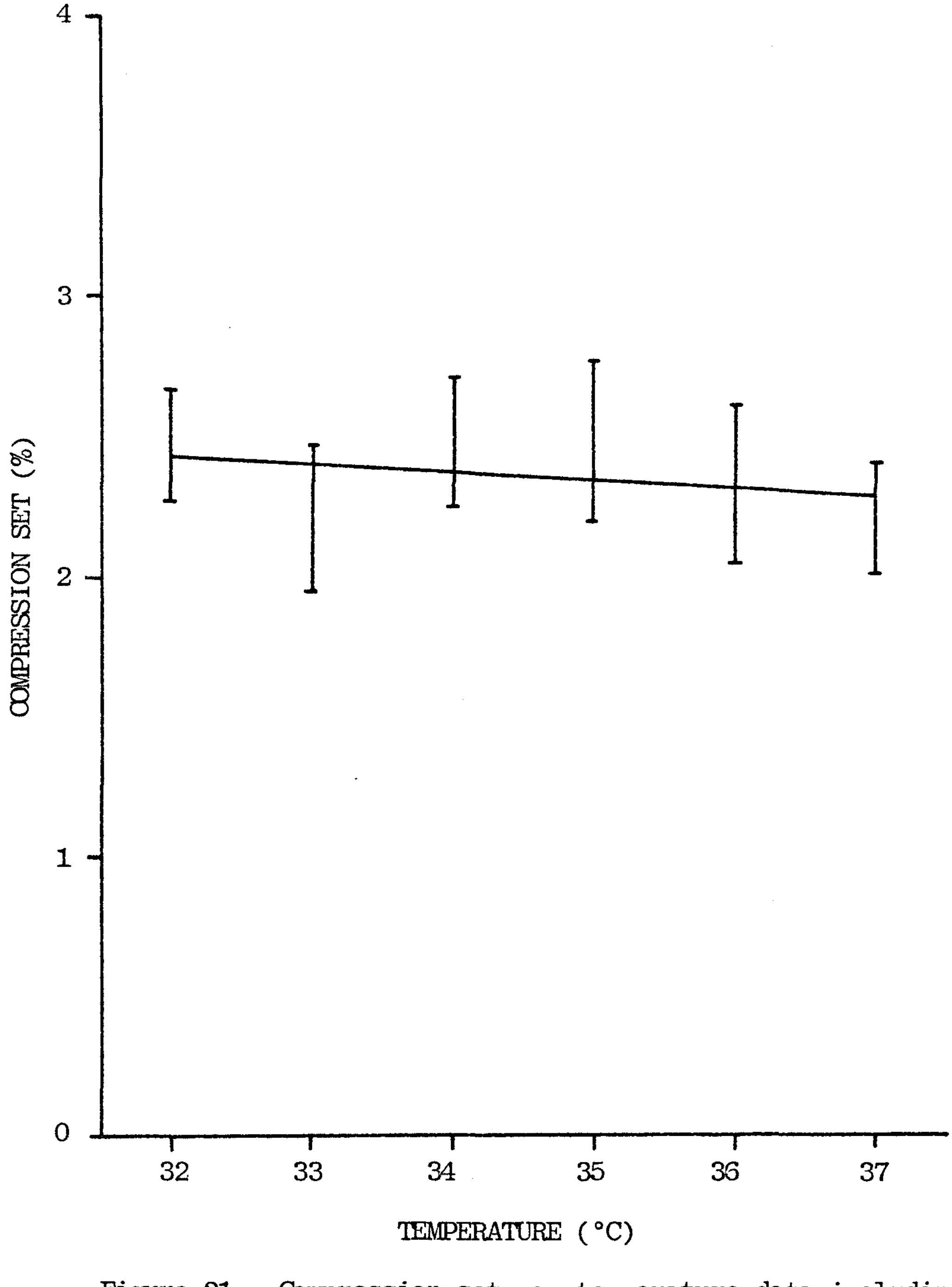


Figure 21. Compression set vs. temperature data including regression line for Impregum polyether impression material. (r = -0.413)

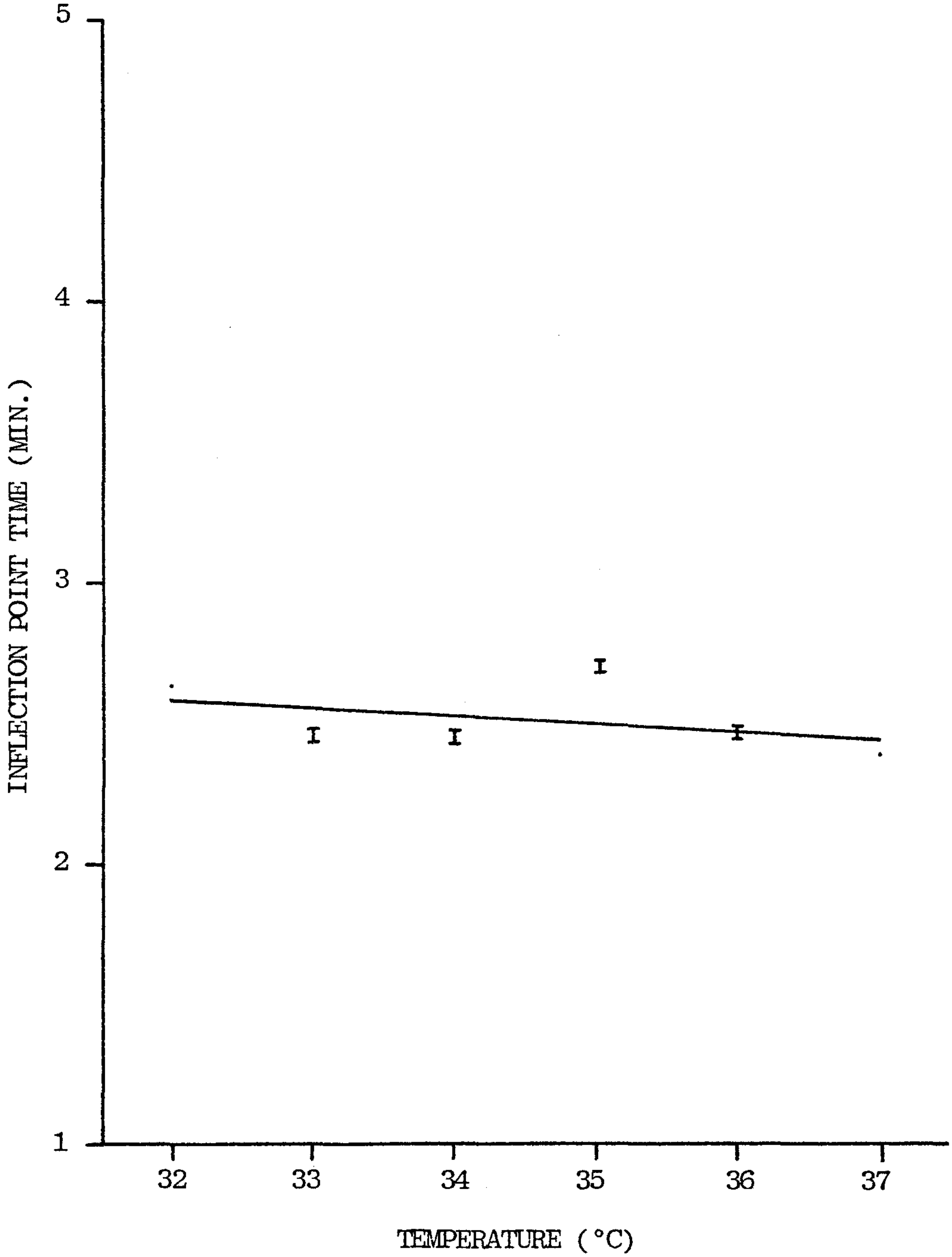


Figure 22. Inflection point time vs. temperature data including regression line for Impregum polyether impression material. (r = -0.427)

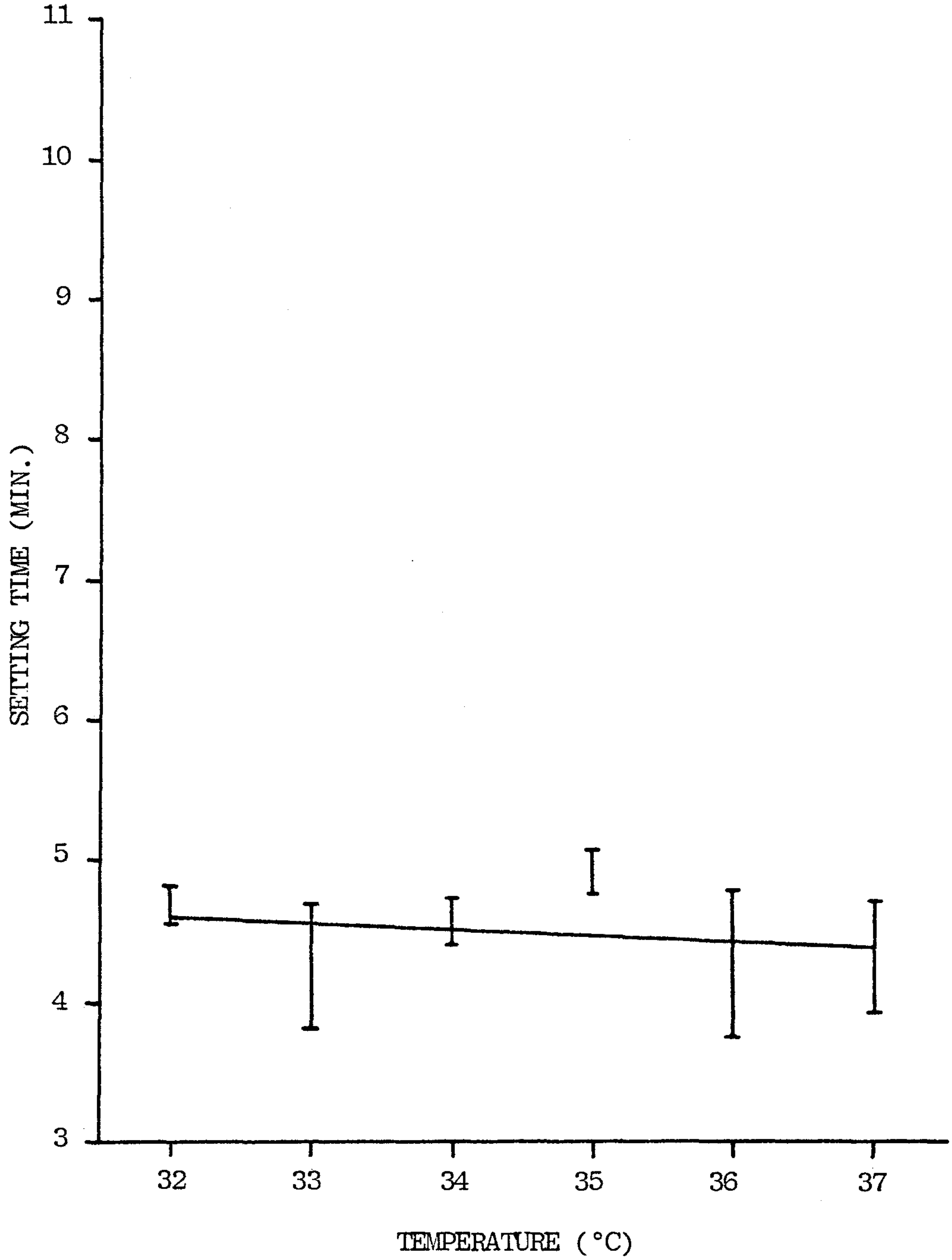


Figure 23. Setting time vs. temperature data including regression line for Impregum polyether impression material. (r = -0.269)

V. Omniflex

A. Compression Set Test Results

1. Physical property requirements (part 1a, Revised ANSI/ADA Specification No. 19): based on mean per cent compression set values obtained this material fails the physical property requirement for type 1 material when tested at 32°C and 33°C. (see Tables IV and V for product comparisons)

2. One-way analysis of variance; compression set (%) vs. temperature (°C): this statistical test indicates that significant ($P < 0.01$) differences in compression set (%) occur between temperatures of 32°C-33°C and 33°C-35°C. (see Table VI for product comparisons)

3. Correlation coefficients (r); compression set (%) vs. temperature (°C): $r = -0.854$. (see Table VII for product comparisons)

4. T-test of manipulation times; 1.5 minutes at 37°C vs. 2.0 minutes at 37°C: this statistical test indicates that no significant differences ($P < 0.05$) in compression set (%) occur between manipulation times of 1.5 minutes at 37°C and 2.0 minutes at 37°C. (see Table VIII for product comparisons)

B. Rheological Test Results

1. Inflection point times and setting times are found in Tables IX and X respectively, and Figure 24 shows a typical rheometer trace for this product.

2. Correlation coefficient (r); inflection point time (minutes) vs. temperature (°C): r = -0.969. (see Table VII for product comparisons)

3. Correlation coefficient (r); setting time (minutes) vs. temperature (°C): r = -0.885. (see Table VII for product comparisons)

4. Correlation coefficient (r); setting time (minutes) vs. inflection point time (minutes): r = +0.998. (see Table VII for product comparisons)

C. Regression Equations (y = mx + b)

1. Compression set (%) vs. temperature (°C): y = -0.8x + 30.2. (graphically shown in Fig. 25)

2. Inflection point time (minutes) vs. temperature (°C): y = -0.343x + 16.5. (graphically shown in Fig. 26)

3. Setting time (minutes) vs. temperature (°C): y = -0.557x + +26.1. (graphically shown in Fig. 27)

4. Setting time (minutes) vs. inflection point time (minutes): y = +1.624 + -0.639.

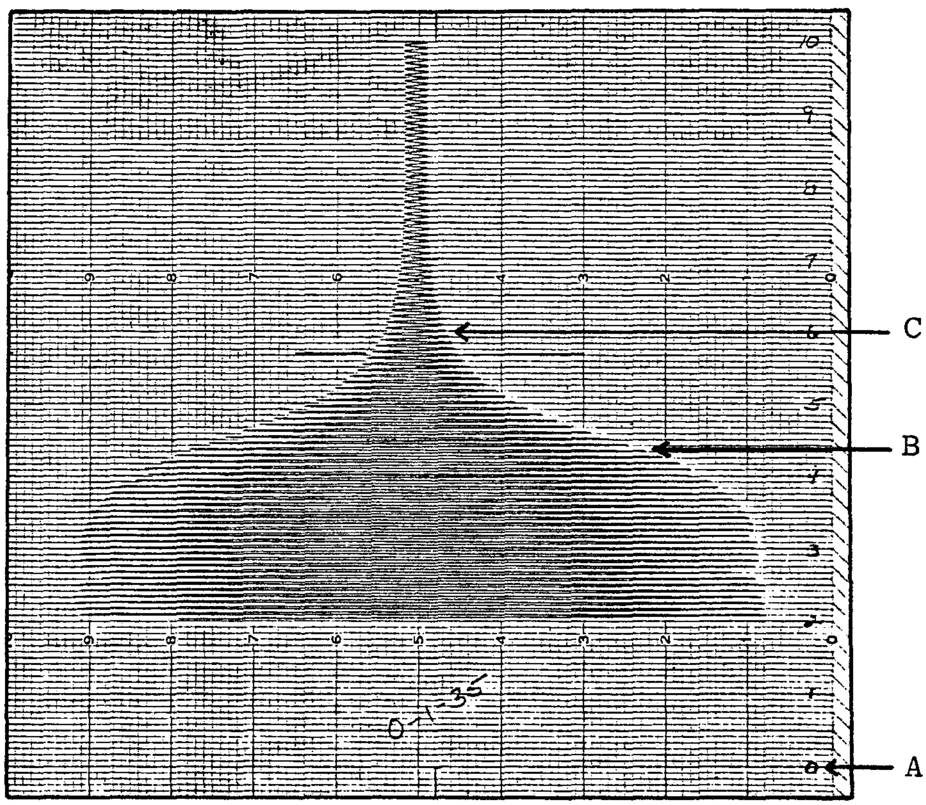


Figure 24. Omniflex: Typical Rheometer Trace (35°C)

A: Start of Mix............. 0.00 min.
B: Inflection Point Time ... 4.38 min.
C: Setting Time .... 6.00 min.

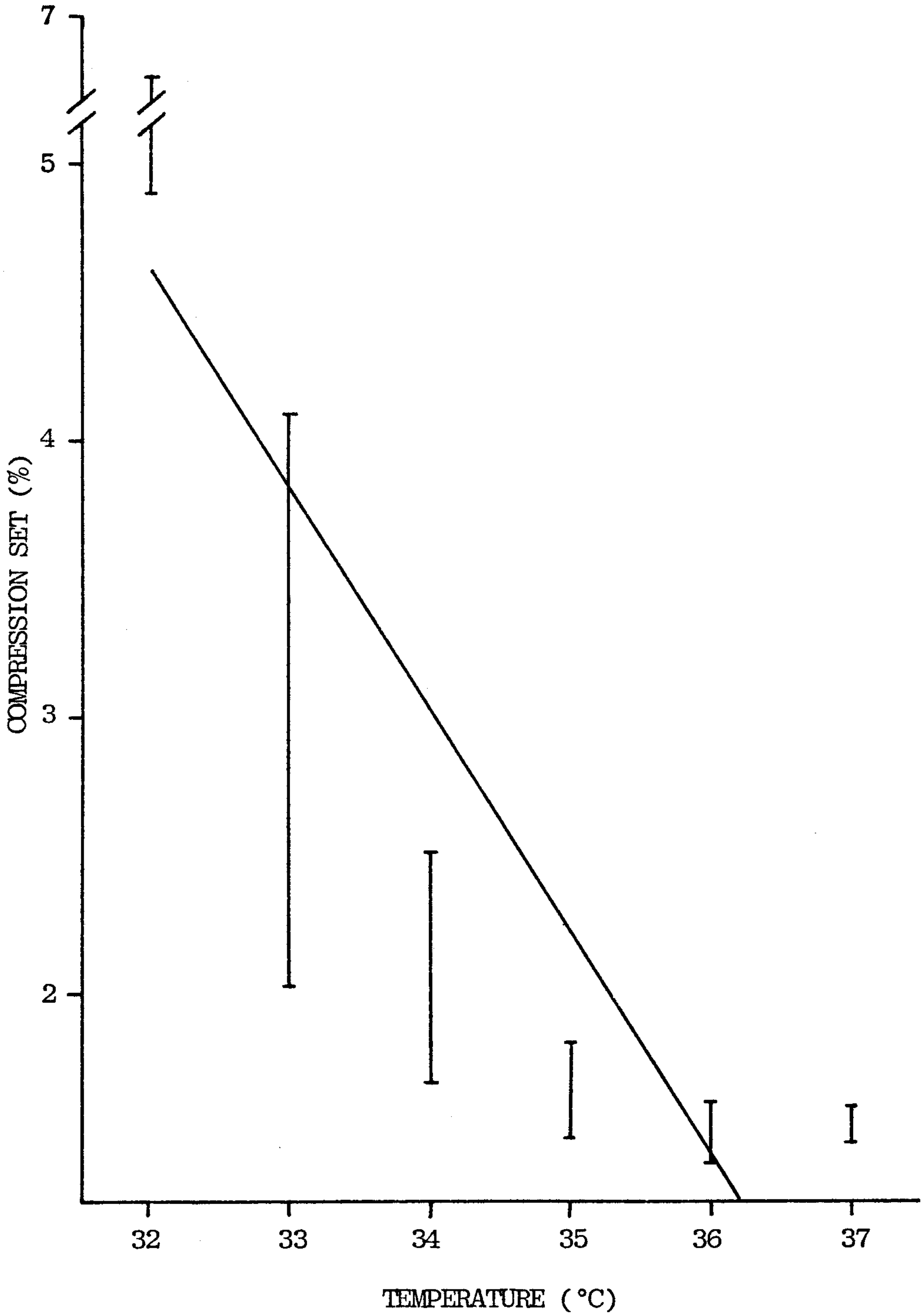


Figure 25. Compression set vs. temperature data including regression line for Omniflex polysulfide impression material. (r = -0.854)

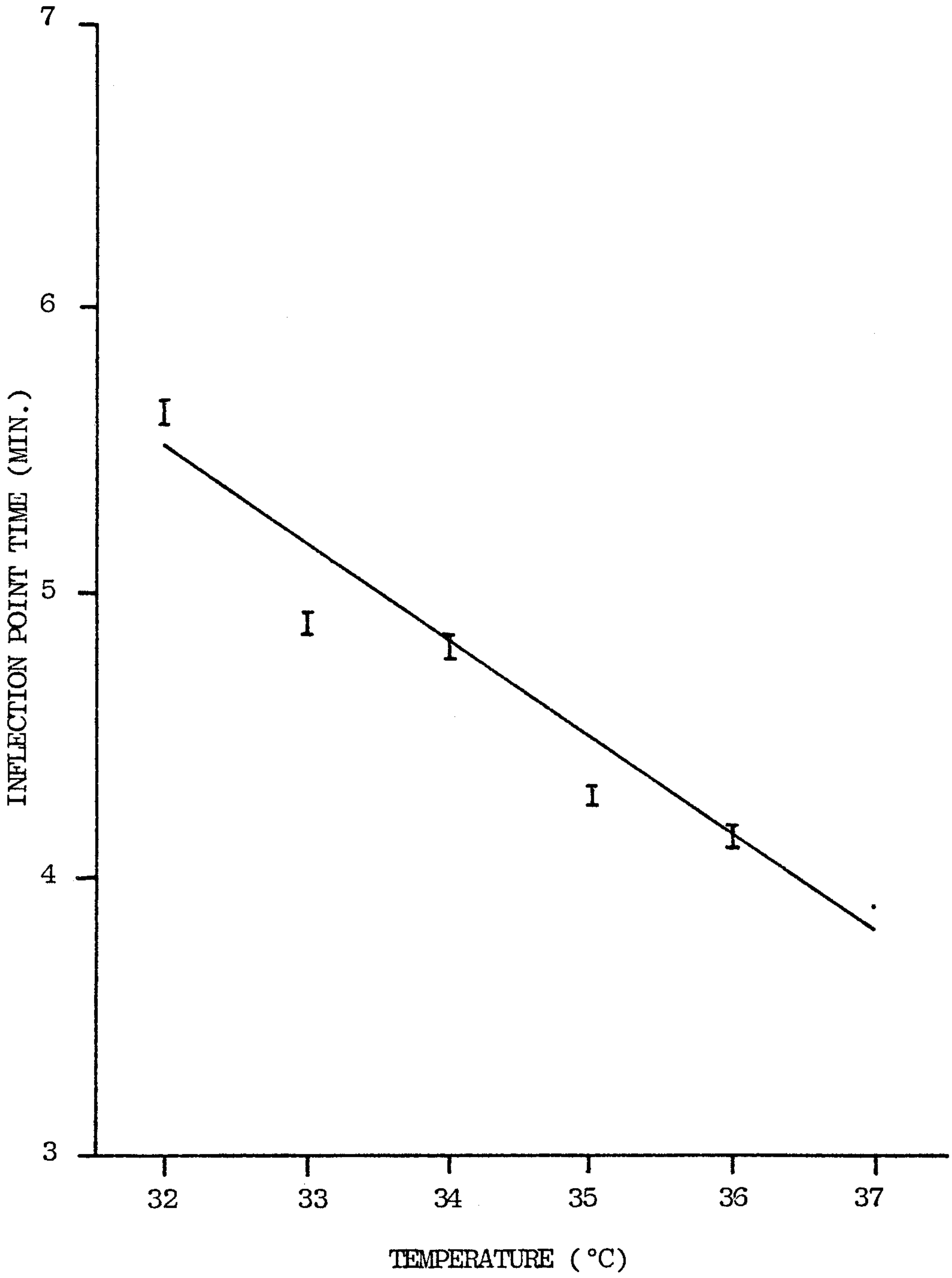


Figure 26. Inflection point time vs. temperature data including regression line for Omniflex polysulfide impression material. (r = -0.969)

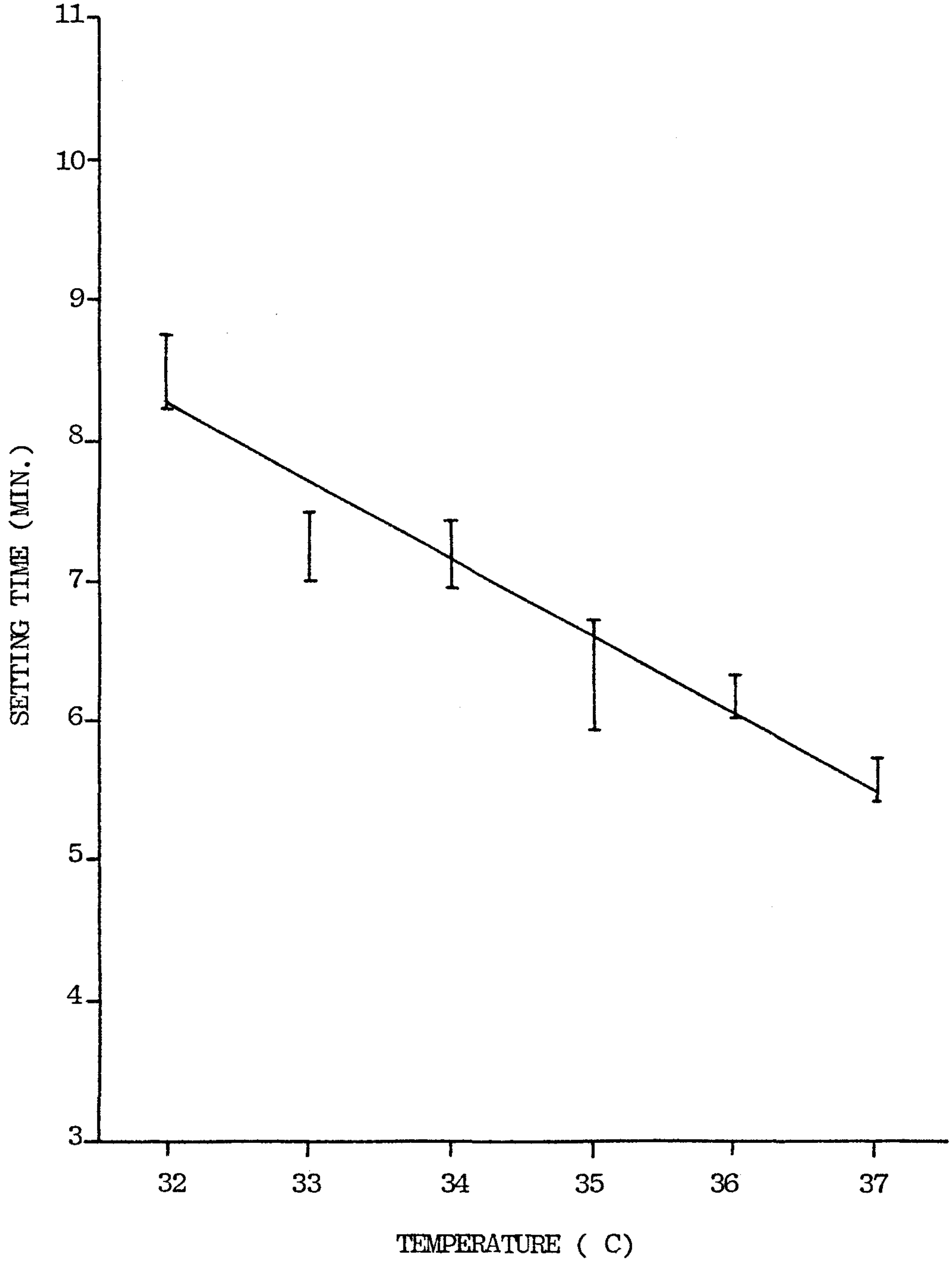


Figure 27. Setting time vs. temperature data including regression line for Omniflex polysulfide impression material. (r = -0.855)

VI. Permlastic

A. Compression Set Test Results

1. Physical property requirements (part 1a, Revised ANSI/ADA Specification No. 19): based on mean per cent compression set values obtained this material fails the physical property requirements for type 3 material when tested at 32°C, 33°C, 34°C and 35°C. (see Tables IV and V for product comparisons)

2. One-way analysis of variance; compression set (%) vs. temperature (°C): this statistical test indicates that significant ($P < 0.01$) differences in compression set (%) occur between temperatures of 32°C-34°C and 33°C-35°C. (see Table VI for product comparisons)

3. Correlation coefficients (r); compression set (%) vs. temperature (°C): $r = -0.842$. (see Table VII for product comparisons)

4. T-test of manipulation times; 1.5 minutes at 37°C vs. 2.0 minutes at 37°C: this statistical test indicates that no significant differences ($P < 0.05$) in compression set (%) occur between manipulation times of 1.5 minutes at 37°C and 2.0 minutes at 37°C. (see Table VIII for product comparisons)

B. Rheological Test Results

1. Inflection point times and setting times are found in Tables IX and X respectively, and Figure 28 shows a typical rheometer trace for this product.
2. Correlation coefficient (r); inflection point time (minutes) vs. temperature (°C): $r = -0.947$. (see Table VII for product comparisons)
3. Correlation coefficient (r); setting time (minutes) vs. temperature (°C): $r = -0.939$. (see Table VII for product comparisons)
4. Correlation coefficient (r); setting time (minutes) vs. inflection point time (minutes): $r = +0.888$. (see Table VII for product comparisons)

C. Regression Equations ($y = mx + b$)

1. Compression set (%) vs. temperature (°C): $y = -0.385x + 19.3$. (graphically shown in Fig. 29)
2. Inflection point time (minutes) vs. temperature (°C): $r = -0.258x + 14.7$. (graphically shown in Fig. 30)
3. Setting time (minutes) vs. temperature (°C): $y = -0.414x + 24.0$. (graphically shown in Fig. 31)
4. Setting time (minutes) vs. inflection point time (minutes): $y = +1.416x + 1.564$.

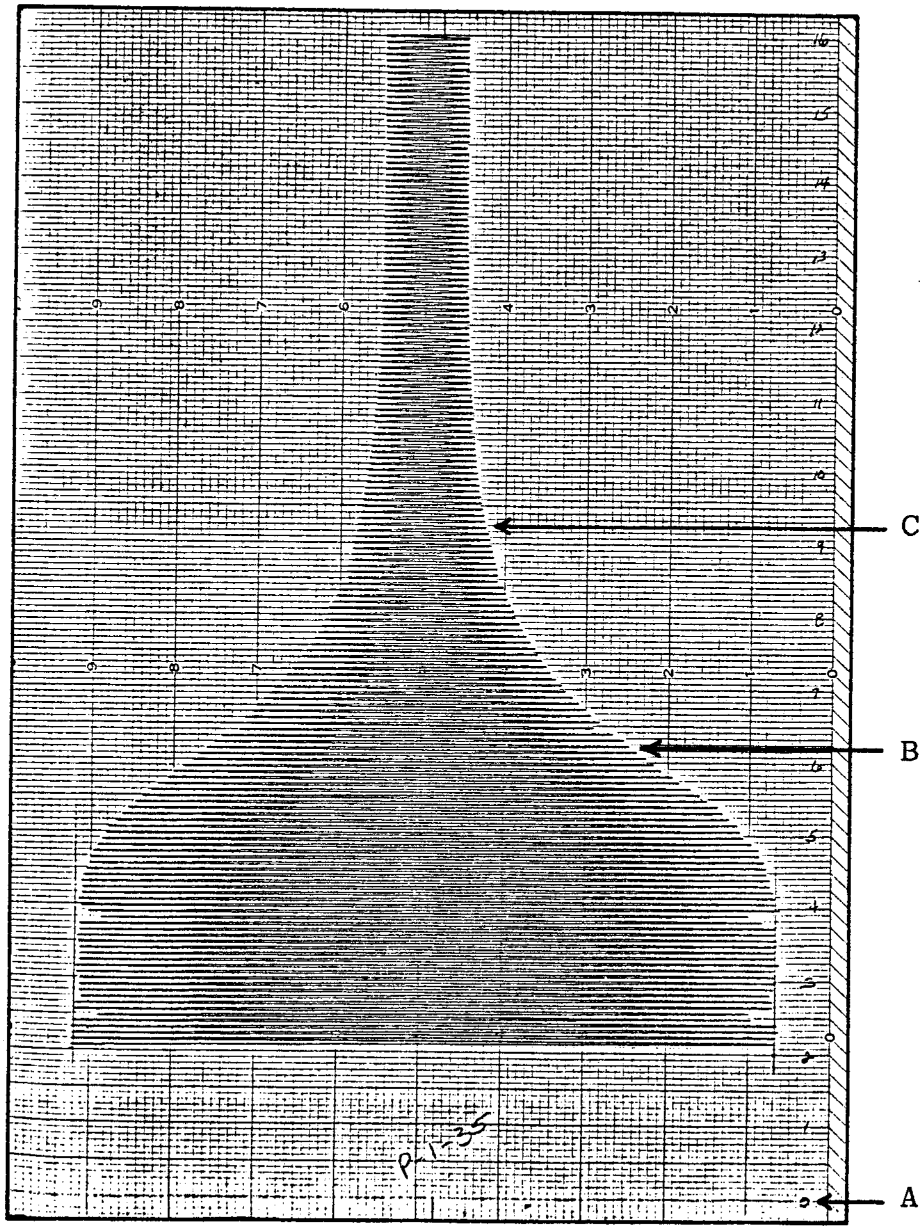


Figure 28. Permlastic: Typical Rheometer Trace (35°C)

A: Start of Mix .... 0.00 min.
B: Inflection Point Time ... 6.38 min.
C: Setting Time .... 9.25 min.

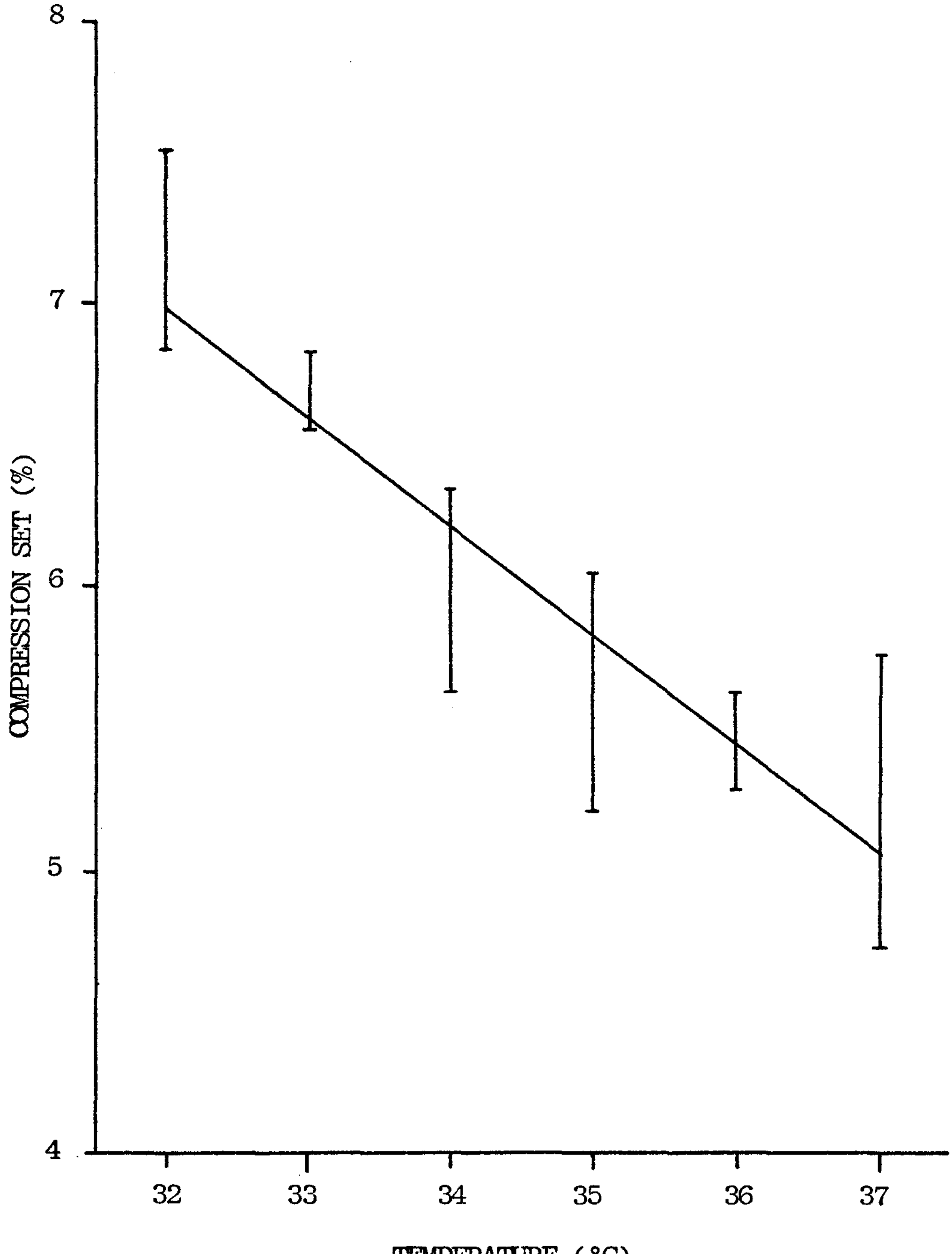


Figure 29. Compression set vs. temperature data including regression line for Permlastic polysulfide impression material. (r = -0.842)

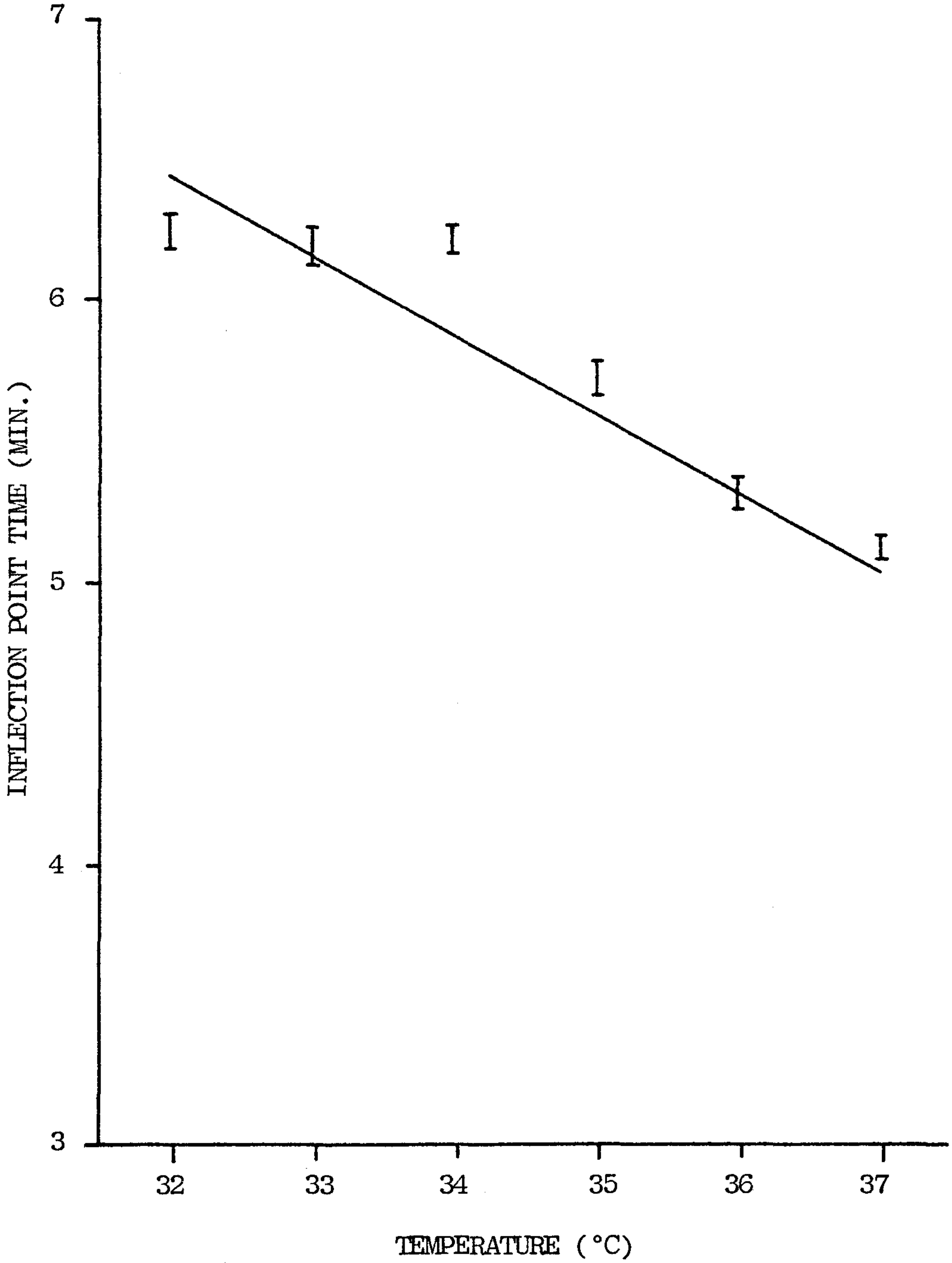


Figure 30. Inflection point time vs. temperature data including regression line for Permlastic polysulfide impression material. (r = -0.947)

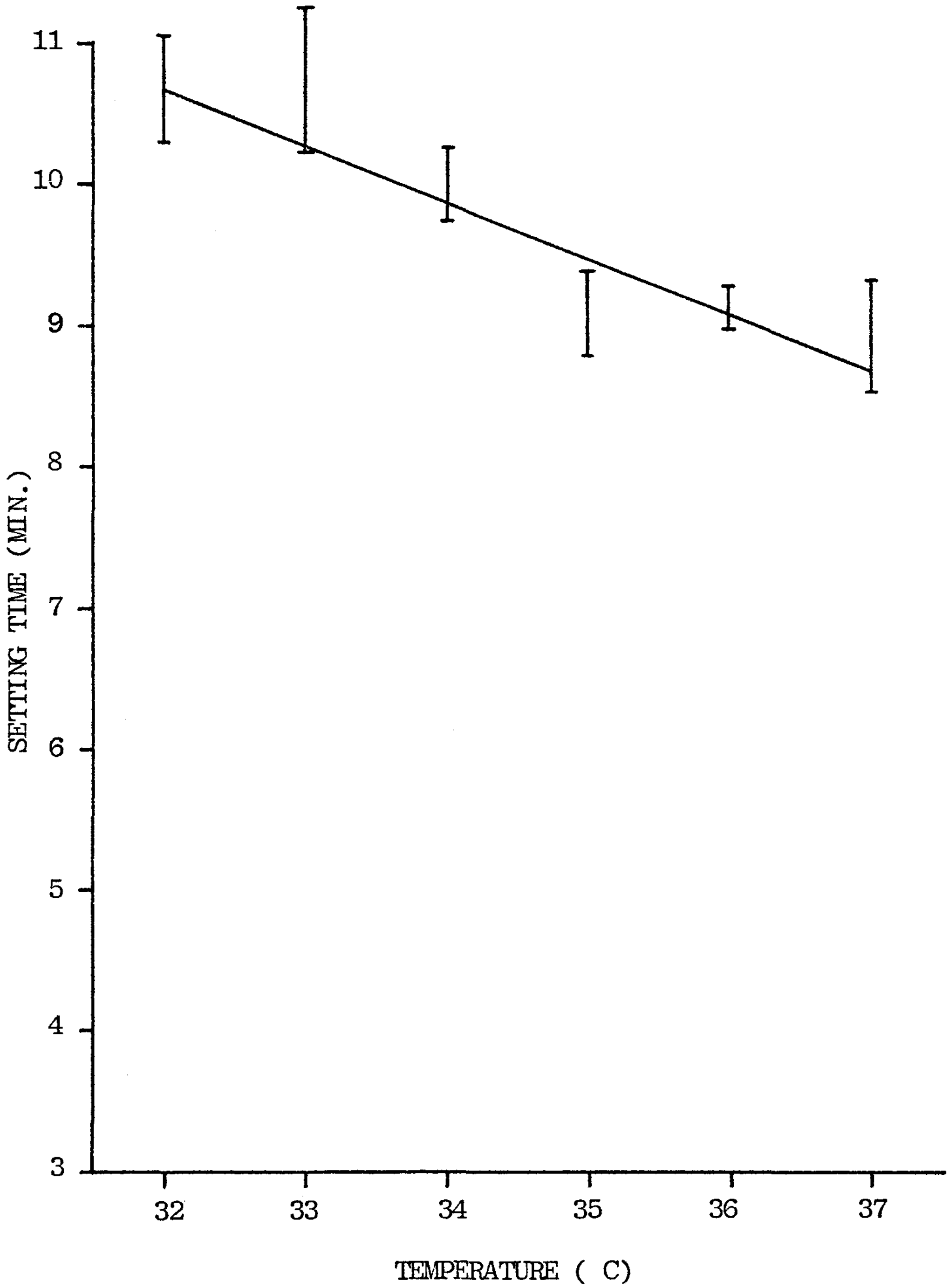


Figure 31. Setting time vs. temperature data including regression line for Permlastic polysulfide impression material. (r = -0.939)

VII. Reflect

A. Compression Set Test Results

1. Physical property requirements (part 1a, Revised ANSI/ADA Specification No. 19): based on mean per cent compression set values obtained this material passes the physical property requirements for type 1 material when tested at 32°C and 1°C increments through 37°C. (see Tables IV and V for product comparisons)
2. One-way analysis of variance; compression set (%) vs. temperature (°C): this statistical test indicates that no significant ($P < 0.01$) differences in compression set (%) occur between temperatures of 32°C through 37°C. (see Table VI for product comparisons)
3. Correlation coefficients (r); compression set (%) vs. temperature (°C): $r = -0.410$. (see Table VII for product comparisons)
4. T-test of manipulation times; 1.5 minutes at 37°C vs. 2.0 minutes at 37°C: this statistical test indicates that no significant differences ($P < 0.05$) in compression set (%) occur between manipulation times of 1.5 minutes at 37°C and 2.0 minutes at 37°C. (see Table VIII for product comparisons)

B. Rheological Test Results

1. Inflection point times and setting times are found in Tables IX and X respectively, and Figure 32 shows a typical rheometer trace for this product.
2. Correlation coefficient (r); inflection point time (minutes) vs. temperature (°C): r = -0.952. (see Table VII for product comparisons)
3. Correlation coefficient (r); setting time (minutes) vs. temperature (°C): r = -0.732. (see Table VII for product comparisons)
4. Correlation coefficient (r); setting time (minutes) vs. inflection point time (minutes): r = +0.987. (see Table VII for product comparisons)

C. Regression Equations (y = mx + b)

1. Compression set (%) vs. temperature (°C): y = -0.0058x + 0.376. (graphically shown in Fig. 33)
2. Inflection point time (minutes) vs. temperature (°C): y = -0.202x + 10.5. (graphically shown in Fig. 34)
3. Setting time (minutes) vs. temperature (°C): y = -0.286x + 14.2. (graphically shown in Fig. 35)
4. Setting time (minutes) vs. inflection point time (minutes): y = +1.35x + -0.338.

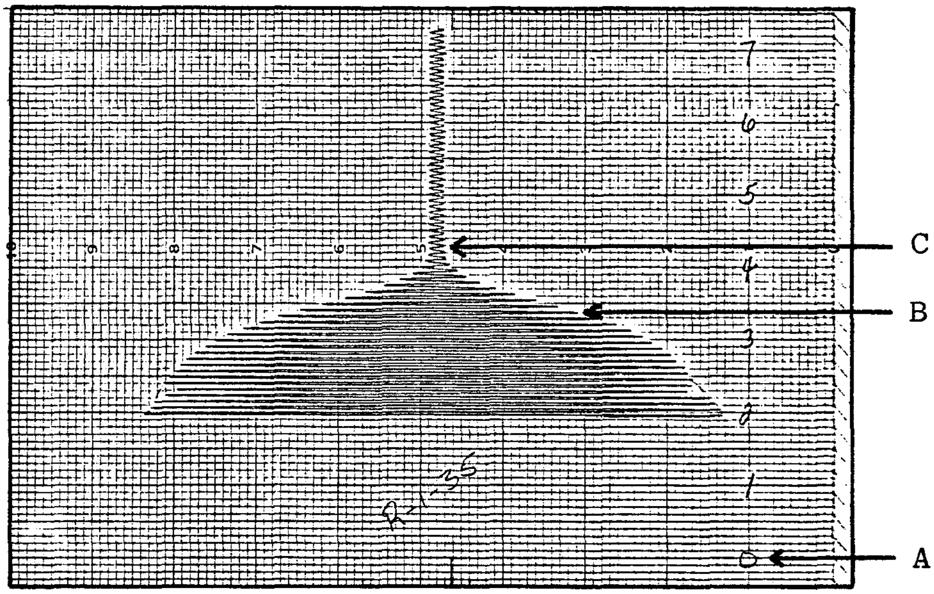


Figure 32. Reflect: Typical Rheometer Trace (35°C)

A: Start of Mix .... 0.00 min.
B: Inflection Point Time .... 3.38 min.
C: Setting Time .... 4.25 min.

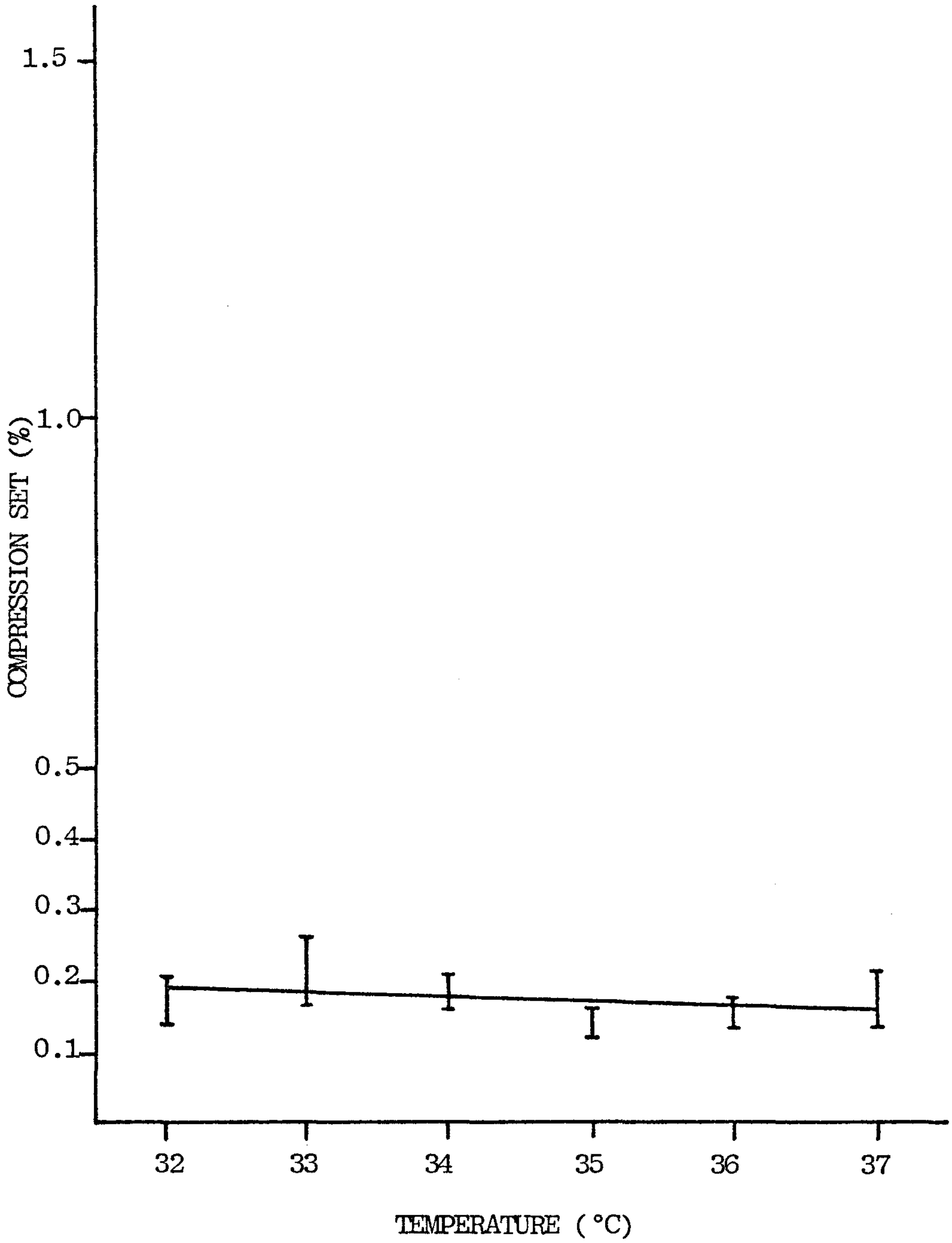


Figure 33. Compression set vs. temperature data including regression line for Reflect silicone impression material. (r = -0.410)

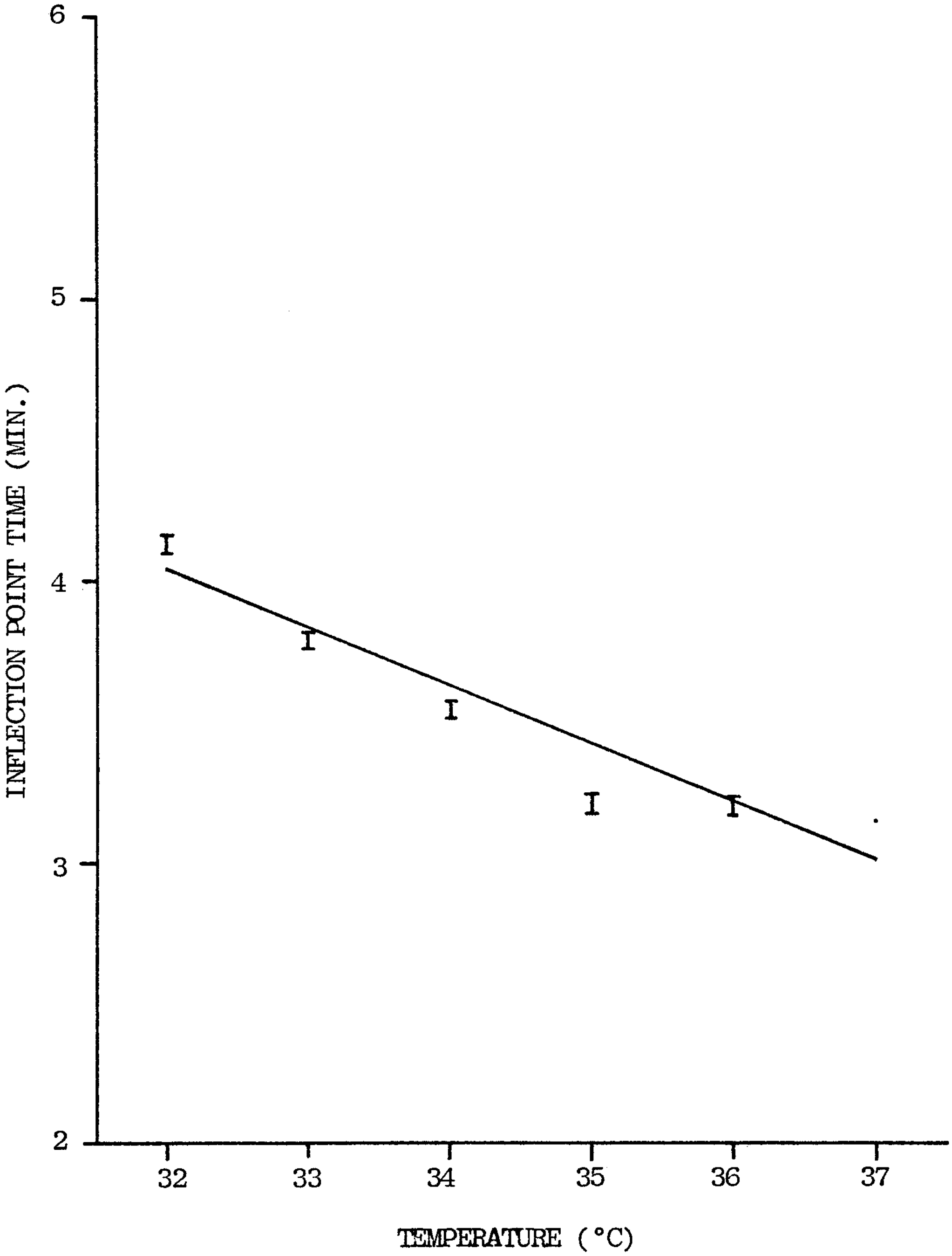


Figure 34. Inflection point time vs. temperature data including regression line for Reflect silicone impression material. (r = -0.952)

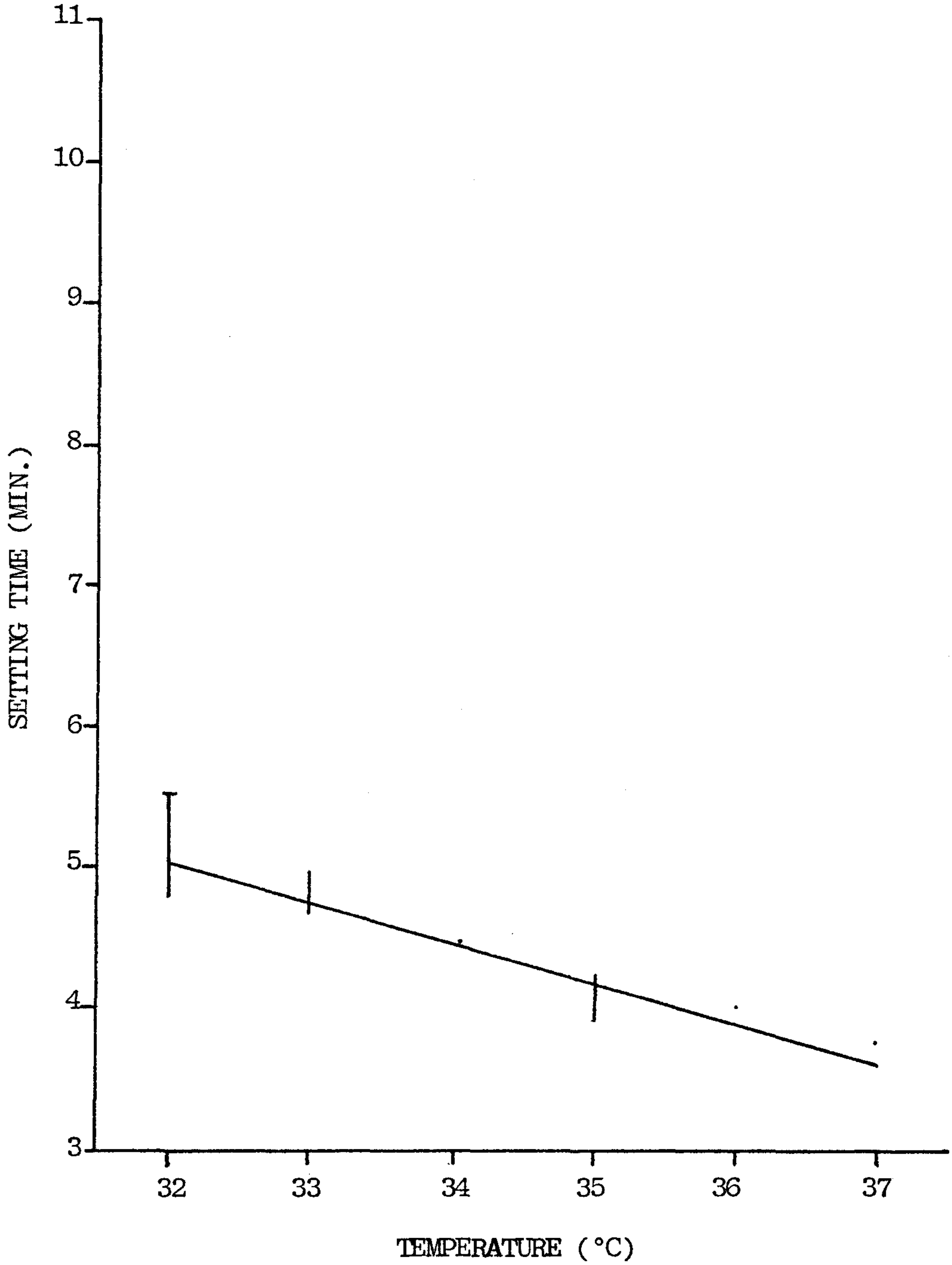


Figure 35. Setting time vs. temperature data including regression line for Reflect silicone impression material. (r = -0.732)

TABLE IV

ANSI/ADA Physical Property Requirements for

Maximum Per Cent Compression Set

Material Name	Temperature (°C)					
	32	33	34	35	36	37
Accoe	P	P	P	P	P	P
Coe-flex	F	F	F	F	F	F
Elasticon	P	P	P	P	P	P
Impregum	P	P	P	P	P	P
Omniflex	F	F	P	P	P	P
Permlastic	F	F	F	F	P	P
Reflect	P	P	P	P	P	P
	Pass = P Fail = F					

TABLE V

Per Cent Compression Set of Elastomeric Impression Materials as a Function of Temperature

Material Name	Compression Set (%)					
	32°C	33°C	34°C	35°C	36°C	37°C
Accoe	4.416±0.475	4.297±0.526	2.867±0.441	3.143±0.325	3.394±0.821	3.349±0.196
Coe-flex	4.501±0.106	4.051±0.246	3.639±0.159	3.332±0.121	2.863±0.111	2.641±0.113
Elasticon	1.344±0.085	1.123±0.069	1.024±0.059	0.889±0.041	0.811±0.047	0.783±0.043
Impregum	2.470±0.197	2.203±0.261	2.473±0.226	2.481±0.273	2.325±0.281	2.179±0.198
Omniflex	5.637±0.731	3.062±1.019	2.111±0.416	1.667±0.170	1.504±0.098	1.532±0.057
Permlastic	7.192±0.346	6.689±0.121	5.980±0.353	5.625±0.408	5.449±0.166	5.251±0.479
Reflect	0.173±0.034	0.219±0.048	0.188±0.021	0.142±0.023	0.158±0.019	0.178±0.043

TABLE VI

Analysis of Variance to Determine Significant Difference

Between Testing Temperatures

Temperature Difference	Material Name						
	Accoe	Coe-flex	Elasticon	Impregum	Omniflex	Permlastic	Reflect
32-33°C	O	X	X	O	X	O	O
32-34°C	X	X	X	O	X	X	O
32-35°C	X	X	X	O	X	X	O
32-36°C	O	X	X	O	X	X	O
32-37°C	O	X	X	O	X	X	O
33-34°C	X	X	O	O	O	O	O
33-35°C	X	X	X	O	X	X	O
33-36°C	O	X	X	O	X	X	O
33-37°C	O	X	X	O	X	X	O
34-35°C	O	X	O	O	O	O	O
34-36°C	O	X	X	O	O	O	O
34-37°C	O	X	X	O	O	O	O
35-36°C	O	X	O	O	O	O	O
35-37°C	O	X	O	O	O	O	O
36-37°C	O	O	O	O	O	O	O

Significant Difference ($P < 0.01$): Yes = X No = O

TABLE VII

Correlation Coefficients (r)

Material Name	Setting Time vs. Temperature	Inflection Point Time vs. Temperature	Compression Set vs. Temperature	Setting Time vs. Inflection Point Time
Accoe	-0.949	-0.887	-0.657	+0.766
Coe-flex	-0.979	-0.828	-0.989	+0.896
Elasticon	-0.898	-0.906	-0.968	+0.855
Impregum	-0.269	-0.427	-0.413	+0.871
Omniflex	-0.855	-0.969	-0.854	+0.998
Permlastic	-0.939	-0.947	-0.842	+0.888
Reflect	-0.732	-0.952	-0.410	+0.987

TABLE VIII

Two Sample T-test of Compression Set Data

Material Name	Manipulation Time (min.)	Sample Size	Mean	Standard Deviation	T Value*	Sign. Level
Accoe	1.5	7	3.3491	0.196	3.906	0.0036
	2.0	8	2.6398	0.469	Reject	
Coe-flex	1.5	6	2.6408	0.133	-1.199	0.2647
	2.0	5	2.7090	0.075	Accept	
Elasticon	1.5	5	0.7827	0.043	2.907	0.0271
	2.0	5	0.6734	0.072	Reject	
Impregum	1.5	6	2.1792	0.198	1.832	0.1043
	2.0	5	1.9771	0.168	Accept	
Omniflex	1.5	5	1.5324	0.057	1.976	0.0887
	2.0	5	1.4663	0.048	Accept	
Permlastic	1.5	7	5.2514	0.479	1.761	0.1060
	2.0	8	4.8428	0.411	Accept	
Reflect	1.5	5	0.1779	0.043	1.350	0.2257
	2.0	5	0.1474	0.026	Accept	

* Based on 95% probability ($P < 0.05$)

TABLE IX

Time of Inflection Point of Oscillating Rheometer Trace of Elastomeric Impression Materials as a Function of Temperature

Material Name	Time (minutes)* ($\bar{x}$±s)					
	32°C	33°C	34°C	35°C	36°C	37°C
Accoe	5.38±0.84	5.79±0.52	5.29±1.18	4.21±1.81	4.29±0.52	4.04±0.76
Coe-flex	4.88±0.43	4.63±0.00	3.63±0.90	3.96±0.14	3.29±1.01	3.71±0.29
Elasticon	3.63±0.20	3.63±0.00	3.46±0.14	3.29±0.14	3.04±0.14	3.21±0.14
Impregum	2.63±0.00	2.46±0.14	2.46±0.14	2.71±0.14	2.46±0.14	2.38±0.00
Omniflex	5.63±0.31	4.88±0.25	4.81±0.13	4.29±0.14	4.13±0.25	3.88±0.00
Permlastic	6.25±0.66	6.21±0.52	6.21±0.29	5.71±0.63	5.31±0.55	5.04±0.14
Reflect	4.13±0.25	3.79±0.14	3.54±0.14	3.21±0.14	3.21±0.14	3.13±0.00

* From beginning of mix (includes 1.5 minutes for manipulation)

TABLE X

Setting Time of Elastomeric Impression Materials

as a Function of Temperature

Material Name	Time (minutes)* ($\bar{x}$±s)						
	32°C	33°C	34°C	35°C	36°C	37°C	Mfr's. Setting Time**
Accoe	10.75±0.35	10.42±0.76	9.58±0.63	9.92±1.53	8.67±0.95	7.92±0.88	7.5
Coe-flex	8.25±0.25	7.92±0.14	7.25±0.25	6.75±0.25	6.25±0.43	6.25±0.25	10.0
Elasticon	6.25±0.43	6.38±0.14	6.33±0.14	6.00±0.43	5.33±0.14	5.08±0.29	7.5
Impregum	4.67±0.14	4.25±0.43	4.58±0.14	4.92±0.14	4.25±0.50	4.33±0.38	4.5
Omniflex	8.50±0.25	7.25±0.25	7.19±0.24	6.33±0.38	6.17±0.14	5.58±0.14	7.5
Permlastic	10.69±0.38	10.75±0.50	10.00±0.25	9.08±0.29	9.13±0.14	8.92±0.38	7.5
Reflect	5.17±0.38	4.83±0.14	4.50±0.00	4.08±0.14	4.00±0.00	3.75±0.00	5.5

* Includes 1.5 minutes manipulation time at room temperature.
** Manufacturer's recommended time in the mouth plus 1.5 minutes manipulation time.

DISCUSSION

A combination of manipulative and testing variables have been found to greatly influence the mechanical and physical properties of elastomeric impression materials by having a direct effect on the polymerization process. Included among these testing parameters is the influence of time and temperature. Because these elastomers are used in the oral cavity the temperature of the oral environment becomes an important consideration when testing these materials in the laboratory.

When the Revised ANSI/ADA Specification No. 19 became effective in 1977 the standard testing temperature of 37°C used to simulate oral conditions for test procedures was adjusted to a lower temperature of 32°C as well as a decrease in manipulation time of 30 seconds. The rationale for this adjustment is obscure, although Elborn and Wilson[28] found temperatures attained by elastomers in the mouth to be 31.2°C to 32.1°C and Sandrik and Sarna[29] found this temperature to be 35.3°C.

While it is important to consider the material at the start of mix having a lower temperature (ambient) before being subjected to the oral cavity, and "open" mouth temperature vs. "closed" mouth temperature, factors such as: heat of spatulation, specific heat, heat of reaction and thermal conductivity when evaluating testing temperatures, must not be discounted.

As a result of this lowered testing temperature of 32°C certain elastomers have been shown to be incompletely set and yield inconsistant results. Thus, it was the purpose of this investigation to study the effects of testing temperatures between 32°C and 37°C in 1°C increments and to determine a practical temperature range for testing elastomeric impression materials. Based on previous studies by Sandrik[29] and Elborn[28] of the temperature attained by elastomers in the mouth, it would appear that a testing temperature of 32°C and 33°C is too low, likewise a testing temperature of 37°C too high, indicating a more practical temperature range of 34°C through 36°C.

Two methods were examined for determining the effects of testing temperatures. The first of these studies involved the Revised ANSI/ADA Specification No. 19, test 4.3.5 for Compression set. The specification includes no direct test for setting time but rather calls for "the development of suitable elastic properties at the time recommended by the manufacturer for removal of the impression" to be evaluated by a pass/fail test for compression set where maximum per cent compression set values are indicated per type material. Specification No. 19 classifies dental elastomers as type 1, 2 or 3 based on three physical property requirements (e.g. maximum compression set) as listed in table 1 of the specification. (Table I)

The second method of choice for determining setting time employs the use of an oscillating rheometer. This instrument is currently being used as a standard test for elastomers in both the United Kingdom and Australia.

The definition of setting time commonly used in rheometer studies is described by the time when the two lines forming the upper and lower perimeter of the deflection pattern become parallel to each other showing constant deflections. However, it was observed in this study that many of the materials tested failed to reach this constant deflection pattern (Figures 8, 12, 16, 20, 24, 28 and 32). One material failed to reach a constant deflection pattern after 20 minutes from the beginning of mix indicating the material was not set by this definition, or this definition was invalid. The latter case probably being more true.

The reason for this lack of parallelism or constant deflection observed in rheometer tracings is most likely attributed to the fact that while the material may indeed be set sufficiently that the impression can be removed from the mouth with a minimum amount of distortion, some materials (i.e. conventional silicones) may continue to polymerize for a considerable amount of time (days). This large time span in which polymerization and/or cross-linking continues is commonly referred to as the curing time. Chain lengthening in polysulfides will cause an increase in viscosity while the subsequent cross-linking makes a three dimensional network giving rise to the elastic properties of the material.

Because of the inability in applying this definition to the rheological data, a new empiracal definition of setting time was proposed. This new setting time is defined as the time (minutes) beyond the inflection point as indicated by the initial point where the magnitude of deflection decreases by 1 mm or less over a 15 second time interval.

The inflection point time is defined as the time (minutes) when the midpoint between a changing curve from convex to concave occurs as a function of a rapid increase in viscosity. This measurement of time was examined to see what correlations could be made to other parameters such as setting time, compression set and temperature, and secondly, because this time can easily be reproduced with exactness.

The correlation coefficient is a measure of the degree of closeness of the linear relationship between two variables. When setting time, inflection point and compression set are correlated with temperature it can be shown that good correlations exist for most materials except Impregum (Table VII). The best of the three temperature correlations can be made with inflection point time, which in turn shows good correlation with setting time. Therefore, a model has been created that not only displays temperature sensitivity, but also a definition of setting time that can easily be reproduced.

The nature of correlation coefficients is to be either positive or negative, and this information relates the effect of one variable on another. For example, in the correlation of compression set, setting time and inflection point time against temperature it has been shown that correlation coefficients indicating a decrease in one variable is associated with an increase in the other variable. Thus, it was observed that for all materials tested when temperature is increased from 32°C to 37°C there is an associated decrease in compression set, setting time and inflection point time.

Conversely, when the correlation of setting time vs. inflection point time is examined, a positive correlation coefficient indicating a decrease in one variable is associated with a decrease in the other variable. Likewise, an increase in one variable reflects an increase in the other. Thus, it was observed that for all materials tested an increase in temperature from 32°C to 37°C reflects a decrease in the setting time as well as a decrease in inflection point time.

It appears that the setting time indicated by the oscillating rheometer, at best, gives an estimate of the region in which the rate of polymerization is greatly reduced, however, it gives no indication as to how long the reaction will continue.

Upon examining setting time at 32°C with the manufacturer's recommended setting time (Table X), it can be observed that four materials (Accoe, Impregum, Omniflex and Permlastic) require longer setting times than stated by the manufacturer, three of which (Coe-flex, Omniflex and Permlastic) fail physical property requirements for compression set as shown in Table IV. Although setting time is an empiracal definition for interpreting rheometer traces it can be stated that these materials when tested at 32°C are not completely set. This suggests that either an increase in temperature or an increase in the manufacturer's time in the mouth is necessary for these materials to reach an optimal degree of set. Good correspondence can be seen when the manufacturer's recommended time in the mouth plus 1.5 minutes manipulation time is compared to setting time at 35°C (Table X). However, Accoe and Permlastic do not show this correspondence. Furthermore, Permlastic did not meet the specification for compression set at 35°C which indicates the manufacturer's setting time may be too short. Despite these exceptions this data further lends credibility to the choice of 35°C as the optimum temperature at which these materials should be tested.

In addition to the lowered temperature of 32°C used to simulate oral environments, the revision of specification No. 19 has made an adjustment in the manipulation time (time period from start of mix to when the impression material is placed within an oral environmental state) of 2.0 minutes to a lesser time of 1.5 minutes.

All seven elastomers were tested for compression set at a constant temperature of 37°C, but with contrasting manipulation times of 1.5 and 2.0 minutes respectively. Results from a T-test analysis (Table VIII) indicate no significant difference ($P < 0.05$) when manipulation times are increased by 30 seconds for all materials except Accoe and Elasticon, both of which are conventional silicones. This test indicates that an increased manipulation time of 2.0 minutes has little if any effect on the elastic properties of most of the elastomers studied, but only at temperatures of 37°C. However, the increase in manipulation time of 30 seconds may show more significance at reduced temperatures where some materials fail physical property requirements for compression set.

Based on one-way analysis of variance of compression set vs. temperature (Table VI), Elasticon and Coe-flex exhibit the most sensitivity to temperature while Impregum and Reflect show the least. This observation led to the generalization that elastomers involving no by-product formation will show little or no temperature sensitivity. Concommitantly, a significant ($P < 0.01$) decrease in compression set can be observed with an increase in temperature in the range of 32°C through 37°C for those elastomers involving condensation reactions. Contrary to this analysis it could be stated that because Reflect and Impregum are in the oral cavity for such a short period of time (3 and 4 minutes respectively) and because their reactions occur rapidly, temperature sensitivity cannot be measured.

The search to find an ideal testing temperature for all elastomers is a difficult task not only because of the nature of their respective reactions (e.g. condensation) but also because of the many variables previously discussed.

Upon careful examination of the elastomers (Accoe, Coe-flex, Elasticon, Omniflex and Permlastic), which show significant ($P < 0.01$) temperature differences, a practical testing temperature can be observed in Table VI where an increase in temperature has no significance on compression set. Temperatures of 32°C and 33°C are not practical because three materials (Coe-flex, Omniflex, and Permlastic) fail physical property requirements for compression set, but pass at higher temperatures except for Coe-flex which fails at all temperatures tested. Temperatures of 32°C and 37°C likewise appear to be impractical based on previous investigations measuring the temperature rise of elastomers in the mouth. The elimination of these temperatures (32°C, 33°C and 37°C) leaves a more practical temperature range of 34°C through 36°C.

Based on one-way analysis of variance for compression set where an increase in temperature has no significance ($P < 0.01$) on compression set the following difference and "no difference" can be observed in Table VI within the practical range of temperatures for each material: Accoe, 33°C-34°C, "34°C-35°C"; Coe-flex, 35°C-36°C, "36°C-37°C"; Elasticon, 33°C-35°C, "35°C-36°C"; Omniflex, 33°C-35°C, "35°C-36°C"; and Permlastic, 33°C-35°C, "35°C-36°C". Therefore, the greatest temperature within the practical temperature range (34°C through 36°C) where an increase in temperature has no significance to compression set values is as follows: Accoe, 34°C; Coe-flex, 36°C; Elasticon, 35°C; Omniflex, 35°C and Permlastic, 35°C.

Based on all the available information it appears that 35°C is the most practical testing temperature for all elastomers studied in this investigation. However, it should be noted that Permlastic exhibits the greatest amount of deformation of all materials tested and is the one of two materials tested, the other being Coe-flex, that failed physical property requirements for compression set at a temperature of 35°C. The logical solution to this problem would then call for the manufacturer to adjust (increase) the time for which these materials remain in the mouth.

As a result of a lowered testing temperature of 32°C, certain elastomers have been shown to be incompletely set and to yield inconsistant results. The effects of testing temperatures have been studied in the range of temperatures from 32°C through 37°C to determine the most practical testing temperature. It was determined that some materials fail physical property requirements under ANSI/ADA Specification No. 19 test for compression set and that some materials require longer setting times than that stated by the manufacturer. It was also determined that a 30 second increase in manipulation time had no significant effect on most materials when tested at 37°C. Temperature sensitivity was observed in all materials tested and an increase in temperature will decrease per cent compression set as well as setting time giving more desirable results. A temperature of 35°C has been selected as the most practical temperature for testing elastomeric impression materials.

SUMMARY

The elastic recovery of elastomeric impression materials when withdrawn from the oral cavity is critical to both patient and practioner. In an effort to contribute fundamental testing criterion, seven elastomers were selected and investigated at temperatures of 32°C at 1°C increments through 37°C. The behavior exhibited by these elastomers was examined under the provisions outlined in ANSI/ADA Specification No. 19 for compression set and setting phenomena as a function of temperature using an oscillating rheometer. Statistical analysis of the data exposes the inadequacies of elastomers when subjected to a testing temperature of 32°C as specified under present ANSI/ADA standards of oral environmental simulation, and directs attention to a more realistic testing temperature of 35°C.

CONCLUSIONS

1. Increase in testing temperature results in a reduced setting time as well as a reduction in permanent deformation.
2. Polysulfides and conventional silicones are more sensitive to temperature change in the range of 32°C through 37°C in terms of compression set than are addition silicones and polyethers.
3. The definition of setting time where the deflection of a rheometer trace first deviates one milimeter or less was found to be more reliable than the previous definition of using parallel lines denoted by a constant deflection pattern.
4. An increased manipulation time of 30 seconds has little effect ($P < 0.05$) on per cent compression set when tested at a temperature of 37°C.
5. A temperature of 35°C to simulate clinical conditions is more realistic than 32°C for testing properties of elastomeric impression materials.

REFERENCES

1. Ward, G. Impression Materials and Impression Taking. Br Dent J, 110:118-19, Feb. 21, 1961.

2. Starcke, Jr., Edgar N. A Historical Review of Complete Denture Impression Materials. J Am Dent Assoc, 91:1037-1040, Nov. 1975

3. Fairhurst, C. W., Furman, T. C., Schallhorn, R. V., Kirkpatrick, E. L., and Ryge, G. Elastic Properties of Rubber Base Impression Materials. J Prosthet Dent, 6:534-542, July, 1956.

4. Skinner, Eugene W. The Properties of Rubber Base Impression Materials. Dent Clin North Am, Nov. 1958, p.685-697.

5. Roydhouse, R. H. Elastic Impression Materials. NZ Dent J, 52: 187-190, Oct. 1956.

6. Braden, M. Characterization of the Setting Process In Dental Polysulfide Rubbers. J Dent Res, 45:1065-1071, Aug. 1966.

7. Craig, Robert G. A Review of Properties of Rubber Impression Materials. J Mich Dent Assoc, 59:254-261, April 1977.

8. Miller, Jr., W. A. C., Hansen, W. C., Dickson, George, and Sweeney, W. T. Physical Properties of Synthetic-Rubber-Base Dental Impression Materials. J Am Dent Assoc, 60:211-223, Feb. 1960.

9. McCabe, J. F., and Wilson, H. J. Addition Curing Silicone Rubber Impression Materials. Br Dent J, 145:17-20, July 4, 1978.

10. Braden, M., and Elliott, J. C. Characterization of the Setting Process of Silicone Dental Rubbers. J Dent Res, 45:1016-1023, Aug. 1966.

11. Status Report on Polyether Impression Materials. Council on Dental Materials and Devices. J Am Dent Assoc, 95:126-130, July 1977.

12. Yeh, C. L., Powers, J. M., Craig, R. G. Properties of Addition Type Silicone Impression Materials. J Am Dent Assoc, 101:482-484, Sept. 1980.

13. Skinner, Eugene W., and Cooper, Edwin N. Desirable Properties and Use of Rubber Impression Materials. J Am Dent Assoc, 51:523-536, Nov. 1955.

14. Guide to Dental Materials and Devices, ed. 6. Chicago, American Dental Association, Council on Dental Materials and Devices, 1972, p.221.

15. McLean, John W. Physical Properties Influencing the Accuracy of Silicone and Thiokol Impression Materials. Br Dent J, 110:85-91, Feb. 7, 1961.

16. Wilson, H. J. Elastomeric Impression Materials. Br Dent J, 121:277-283, Sept. 20, 1966.

17. Revised ANSI/ADA Specification No. 19 for Non-Aqueous, Elastomeric Impression Materials. J Am Dent Assoc, 94:733-741, April 1977.

18. Wilson, H. J. A Method of Assessing the Setting Characteristics of Impression Materials. Br Dent J, 117:536-540, Dec. 15, 1964.

19. Anderson, J. N. The Dimensional Stability of Three Silicone-Base Impression Materials. Practitioner, 8:368-372, Aug. 1958.

20. Herfort, Thomas W., Gerberich, William W., Mascosko, Christopher W., and Goodkind, Richard J. Viscosity of Elastomeric Impression Materials. J Prosthet Dent, 38:396-404, Oct. 1977.

21. Inoue, K., and Wilson, H. J. Viscoelastic Properties of Elastomeric Impression Materials. J Oral Rehabil, 5:89-94, 1978.

22. Mansfield, M. A., and Wilson, H. J. Elastomeric Impression Materials. Br Dent J, 132:106-110, Feb. 1, 1972.

23. Cresson, James Suggested Revisions for Testing Dental Elastic Impression Materials. J Dent Res, 28:573-582, Dec. 1949.

24. Jorgensen, K. D. Thiokol as a Dental Impression Material. Acta Odontol Scand, 14:313-334, Jan. 1957.

25. Wilson, H. J. Elastomeric Impression Materials II. Br Dent J, 121:322-328, Oct. 4, 1966.

26. Schwindling, R. Thermal Correction of the Volume Changes of a Silicone Impression Material. Quintessence Int, 2:35-40, Oct. 1971.

27. Nayyar, Arun, Tomlins, Christopher D., Fairhurst, Carl W., and Okabe, Toru. Comparison of Some Properties of Polyether and Polysulfide Materials. J Prosthet Dent, 42:163-167, Aug. 1979

28. Elborn, A., and Wilson, H. J. Temperatures Attained by Impression Materials in the Mouth. Br Dent J, 118:80-82, Jan. 19, 1965.

29. Sandrik, James L., and Sarna, Thomas. Temperature of Elastomeric Impression Materials While Setting in the Mouth. J Dent Res, 59(11):1985-1986, Nov. 1980.

APPENDIX

The following pages contain raw data from rheometer tracings. At 15 second intervals, beginning with 2.0 minutes, measurements of the magnitude of deflection were recorded in cm for the duration of the trace. Included with actual measurements of deflection for each run is the time of inflection, mean time of inflection and standard deviation of the mean.

The tabulated data is a reduced copy taken directly from a computer (MINITAB) print-out and requires a guide for interpretation:

Row 1 shows a letter followed by a number. The letter represents a material, the number represents a temperature. For example, A 36 means Accoe taken at 36 degrees centigrade. (C = Coe-flex, E = Elasticon, I = Impregum, O = Omniflex, P = Permlastic and R = Reflect)

Row 2 shows 2.00, 2.25, 2.50, 2.75, etc. meaning two minutes, two and one quarter minutes, two and one half minutes, and two and three quarter minutes, etc. until .00 is displayed twice. The first .00 indicates the column containing inflection time measurements and, the second .00 indicates the column containing mean inflection time (row 3) and standard deviation (row 4) given in minutes.

Row 3 shows actual measurements in cm of the magnitude of deflection except in columns indicated by .00.

Row 4, 5, etc. give the same information as in row 3, however, each additional row represents additional samples.

PRINT A32

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
19.50	18.90	18.80	18.50	18.40	18.25	17.75	17.50	17.15	16.70	16.45	15.60	15.00	14.40	13.70	12.80	12.00	11.50	10.40	9.65
20.00	19.80	19.70	19.55	19.35	19.05	18.80	18.30	18.00	17.35	16.05	15.70	14.85	13.80	13.00	12.05	11.10	10.10	9.40	8.65
18.60	18.30	18.15	17.75	17.45	17.20	17.00	16.65	16.10	15.35	14.70	13.80	13.15	12.00	11.30	10.30	9.50	8.80	8.15	7.40
19.70	19.55	19.20	18.70	18.25	17.90	17.55	17.05	16.65	16.00	15.45	14.70	13.90	13.00	12.10	11.10	10.20	9.25	8.50	7.65

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
9.00	8.85	7.85	7.35	6.95	6.45	6.00	5.60	5.25	4.95	4.70	4.40	4.20	4.00	3.85	3.65	3.50	3.30	3.20	3.10
8.15	7.55	7.00	6.40	6.15	5.80	5.45	5.10	4.90	4.60	4.40	4.10	3.90	3.75	3.55	3.45	3.35	3.20	3.10	2.95
6.95	6.35	5.95	5.50	5.20	4.80	4.55	4.30	4.10	3.90	3.60	3.40	3.30	3.15	3.00	2.90	2.80	2.65	2.55	2.50
7.00	6.35	5.90	5.40	4.95	4.55	4.20	3.95	3.70	3.45	3.25	3.05	2.90	2.75	2.60	2.45	2.35	2.25	2.20	2.10

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	15.75	16.00	16.25	16.50	16.75
3.00	2.90	2.80	2.70	2.60	2.50	2.45	2.40	2.35	2.25	2.20	2.10	2.05	2.00	1.95	1.90	1.85	1.85	1.80	1.80
2.80	2.75	2.70	2.60	2.50	2.45	2.40	2.35	2.30	2.20	2.15	2.10	2.05	2.00	2.00	1.95	1.95	1.90	1.85	1.80
2.40	2.30	2.25	2.20	2.10	2.05	2.00	1.95	1.90	1.85	1.80	1.75	1.70	1.65	1.60	1.60	1.55	1.55	1.50	1.50
2.00	1.90	1.85	1.80	1.75	1.70	1.60	1.55	1.50	1.45	1.40	1.40	1.35	1.30	1.30	1.30	1.25	1.25	1.20	1.15

17.00	17.25	17.50	17.75	18.00	18.25	18.50	18.75	19.00	19.25	19.50	19.75	20.00	.00	.00
1.75	1.75	1.70	1.70	1.65	1.65	1.60	1.60	1.55	1.50	1.45	1.40	1.40	6.38	5.38
1.80	1.80	1.75	1.70	1.65	1.65	1.65	1.65	1.65	1.60	1.60	1.60	1.55	4.38	.84
1.45	1.40	1.40	1.40	1.35	1.35	1.30	1.30	1.30	1.30	1.30	1.25	1.25	5.13	.00
1.15	1.10	1.10	1.10	1.05	1.05	1.00	1.00	.95	.95	.95	.95	.95	5.63	.00

PRINT A33

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
20.00	19.90	19.75	19.60	19.45	19.15	18.90	18.40	18.00	17.35	16.85	16.05	15.25	14.50	13.55	12.70	11.90	10.95	10.20	9.50
20.00	19.70	19.40	19.10	18.90	18.65	18.30	18.00	17.55	17.05	16.45	15.55	14.70	13.85	13.15	12.20	11.45	10.65	9.95	9.20
19.30	18.80	18.60	18.30	18.00	17.50	17.15	16.50	15.75	14.90	13.90	12.85	11.85	10.75	9.70	8.80	8.10	7.80	6.60	6.00

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
8.75	8.20	7.70	7.20	6.80	6.35	6.00	5.60	5.35	5.05	4.90	4.65	4.40	4.20	4.00	3.85	3.70	3.55	3.45	3.30
8.60	7.85	7.30	6.80	6.40	5.95	5.60	5.30	4.95	4.70	4.45	4.20	4.00	3.80	3.70	3.50	3.40	3.30	3.20	3.00
5.50	5.05	4.65	4.30	4.00	3.70	3.50	3.30	3.10	2.95	2.80	2.60	2.50	2.40	2.35	2.20	2.15	2.05	2.00	1.90

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	15.75	16.00	16.25	16.50	16.75
3.20	3.10	3.00	2.90	2.80	2.70	2.60	2.55	2.50	2.45	2.40	2.35	2.20	2.25	2.15	2.10	2.10	2.05	2.00	2.00
2.90	2.80	2.75	2.65	2.60	2.50	2.40	2.35	2.25	2.20	2.10	2.05	2.05	2.00	2.00	1.90	1.85	1.85	1.80	1.80
1.80	1.75	1.70	1.65	1.60	1.55	1.50	1.50	1.45	1.40	1.40	1.35	1.30	1.30	1.30	1.25	1.25	1.20	1.20	1.15

17.00	17.25	17.50	17.75	18.00	18.25	18.50	18.75	19.00	19.25	19.50	19.75	20.00	.00	.00
1.95	1.90	1.90	1.90	1.85	1.85	1.80	1.75	1.70	1.70	1.70	1.70	1.70	5.38	5.79
1.75	1.70	1.70	1.70	1.65	1.60	1.60	1.60	1.55	1.55	1.50	1.50	1.50	5.63	.52
1.15	1.15	1.10	1.10	1.10	1.10	1.10	1.05	1.05	1.05	1.00	1.00	1.00	6.38	.00

PRINT A34

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
19.70	19.20	18.80	18.40	18.10	17.90	17.40	16.95	16.45	15.85	15.20	14.30	13.40	12.35	11.50	10.65	9.80	9.10	8.85	7.65
19.30	18.40	18.10	17.70	17.40	17.00	16.60	15.80	15.00	14.20	13.05	12.00	10.80	9.90	8.90	8.10	7.20	6.50	5.90	5.40
18.35	18.05	17.80	17.45	17.10	16.65	15.90	15.40	14.60	13.45	12.20	11.05	10.10	9.05	8.10	7.20	6.50	5.85	5.30	4.85

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
7.15	6.55	6.15	5.70	5.40	4.95	4.65	4.40	4.20	4.00	3.80	3.60	3.45	3.30	3.20	3.05	2.90	2.80	2.70	2.60
4.90	4.50	4.15	3.90	3.60	3.40	3.10	2.95	2.80	2.70	2.55	2.40	2.35	2.20	2.10	2.00	1.90	1.80	1.75	1.70
4.50	4.10	3.85	3.55	3.40	3.15	3.00	2.90	2.70	2.55	2.40	2.30	2.20	2.15	2.05	2.00	1.95	1.85	1.80	1.75

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	15.75	16.00	16.25	16.50	16.75
2.50	2.40	2.35	2.25	2.20	2.15	2.10	2.00	1.95	1.90	1.85	1.80	1.80	1.75	1.75	1.70	1.70	1.65	1.60	1.60
1.65	1.60	1.55	1.50	1.45	1.40	1.40	1.40	1.35	1.30	1.25	1.25	1.20	1.20	1.15	1.15	1.15	1.10	1.05	1.05
1.70	1.65	1.60	1.55	1.50	1.45	1.45	1.40	1.40	1.35	1.35	1.30	1.30	1.30	1.25	1.25	1.20	1.20	1.20	1.15

17.00	17.25	17.50	17.75	18.00	18.25	18.50	18.75	19.00	19.25	19.50	19.75	20.00	.00	.00
1.55	1.50	1.50	1.45	1.45	1.45	1.45	1.40	1.40	1.40	1.35	1.30	1.30	6.63	5.29
1.00	1.00	1.00	1.00	.95	.95	.95	.95	.90	.90	.90	.90	.90	4.88	1.18
1.15	1.15	1.10	1.10	1.10	1.05	1.05	1.05	1.00	1.00	1.00	1.00	1.00	4.38	.00

PRINT A35

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
19.60	19.35	19.20	18.95	18.70	18.45	18.25	17.95	17.55	16.80	16.00	15.30	14.30	13.30	12.25	11.30	10.25	9.40	8.70	8.05
18.35	18.05	17.85	17.55	17.35	16.90	16.20	15.40	14.70	13.65	12.40	11.10	10.20	8.75	8.05	7.10	6.50	5.85	5.35	4.90
18.90	18.00	17.55	17.10	16.70	16.00	15.75	15.40	14.95	14.70	14.30	13.75	13.40	12.80	12.15	11.70	11.05	10.35	9.95	9.30

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
7.40	6.70	6.30	5.75	5.40	4.90	4.75	4.50	4.25	4.00	3.80	3.60	3.40	3.25	3.15	3.00	2.90	2.80	2.70	2.60
4.50	4.15	3.90	3.55	3.35	3.10	3.00	2.80	2.70	2.55	2.40	2.30	2.20	2.10	2.05	1.95	1.90	1.85	1.80	1.75
8.70	8.10	7.60	7.05	6.60	6.20	5.80	5.35	4.95	4.60	4.40	4.10	3.90	3.70	3.50	3.35	3.20	3.05	2.95	2.80

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	15.75	16.00	16.25	16.50	16.75
2.50	2.40	2.30	2.30	2.25	2.15	2.10	2.00	1.95	1.90	1.85	1.80	1.80	1.75	1.70	1.70	1.65	1.60	1.60	1.55
1.70	1.60	1.55	1.50	1.45	1.40	1.40	1.40	1.40	1.35	1.35	1.30	1.30	1.30	1.30	1.25	1.20	1.20	1.20	1.15
2.75	2.60	2.50	2.40	2.30	2.20	2.15	2.05	2.00	1.90	1.85	1.80	1.75	1.70	1.65	1.60	1.55	1.55	1.50	1.50

17.00	17.25	17.50	17.75	18.00	18.25	18.50	18.75	19.00	19.25	19.50	19.75	20.00	.00	.00
1.50	1.50	1.45	1.45	1.40	1.40	1.40	1.35	1.35	1.30	1.30	1.30	1.25	5.38	4.21
1.15	1.10	1.05	1.05	1.05	1.05	1.00	1.00	1.00	1.00	.95	.95	.95	5.13	1.81
1.45	1.45	1.40	1.35	1.30	1.30	1.30	1.25	1.25	1.20	1.20	1.15	1.15	2.13	.00

PRINT A36

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
18.60	18.40	17.95	17.60	17.05	16.30	15.65	14.55	13.20	11.70	10.40	9.20	8.10	7.10	6.35	5.60	5.05	4.65	4.20	3.80
19.65	19.10	18.90	18.65	18.35	18.05	17.60	17.10	16.40	15.45	14.70	13.60	12.45	11.40	10.45	9.50	8.60	7.90	7.20	6.65
18.15	17.40	17.05	16.55	16.15	15.70	14.90	13.90	12.70	11.50	10.30	9.20	8.10	7.20	6.30	5.50	5.00	4.50	4.10	3.70

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
3.50	3.20	3.00	2.80	2.60	2.50	2.40	2.25	2.10	2.00	1.90	1.80	1.80	1.75	1.70	1.55	1.50	1.45	1.40	1.35
6.10	5.65	5.20	4.80	4.50	4.20	3.90	3.65	3.50	3.30	3.15	2.95	2.85	2.70	2.60	2.50	2.40	2.35	2.30	2.15
3.40	3.15	2.95	2.70	2.55	2.40	2.30	2.20	2.00	1.90	1.85	1.75	1.70	1.60	1.55	1.45	1.40	1.40	1.35	1.30

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	15.75	16.00	16.25	16.50	16.75
1.35	1.30	1.30	1.25	1.25	1.20	1.20	1.15	1.10	1.10	1.05	1.05	1.00	1.00	1.00	.95	.95	.95	.95	.90
2.10	2.05	2.00	1.95	1.90	1.85	1.75	1.70	1.65	1.60	1.60	1.55	1.55	1.50	1.45	1.45	1.40	1.35	1.35	1.30
1.25	1.20	1.20	1.15	1.15	1.10	1.10	1.05	1.00	1.00	.95	.95	.95	.90	.90	.90	.90	.90	.90	.90

17.00	17.25	17.50	17.75	18.00	18.25	18.50	18.75	19.00	19.25	19.50	19.75	20.00	.00	.00
.90	.90	.90	.90	.90	.90	.90	.90	.85	.85	.85	.80	.80	4.13	4.29
1.30	1.25	1.25	1.25	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.15	1.15	4.88	.52
.90	.85	.85	.80	.80	.80	.80	.80	.80	.80	.80	.80	.80	3.88	.00

PRINT A37

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
18.50	18.10	17.80	17.40	17.00	16.45	15.85	15.20	14.00	12.90	11.90	10.95	9.70	8.70	7.70	7.05	6.35	5.70	5.30	4.90
18.15	17.75	17.05	16.10	14.60	13.45	11.30	9.55	8.20	6.90	5.90	5.10	4.50	3.90	3.50	3.15	2.80	2.60	2.40	2.25
18.20	17.65	17.00	16.35	15.20	15.00	14.05	12.80	11.00	10.25	9.00	7.90	6.95	6.10	5.40	4.85	4.30	3.90	3.55	3.20

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
4.30	4.00	3.75	3.50	3.20	3.00	2.80	2.65	2.55	2.35	2.30	2.20	2.10	2.05	2.00	1.90	1.85	1.80	1.75	1.70
2.05	1.95	1.80	1.75	1.65	1.55	1.50	1.40	1.40	1.35	1.30	1.25	1.25	1.20	1.20	1.15	1.10	1.10	1.05	1.00
2.95	2.75	2.50	2.35	2.20	2.10	1.95	1.90	1.80	1.70	1.65	1.55	1.50	1.45	1.40	1.35	1.30	1.30	1.30	1.25

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	15.75	16.00	16.25	16.50	16.75
1.60	1.55	1.50	1.45	1.40	1.40	1.35	1.35	1.30	1.30	1.25	1.25	1.20	1.20	1.15	1.15	1.10	1.10	1.10	1.10
1.00	1.00	.95	.95	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.85	.85	.80	.80	.80	.80
1.20	1.15	1.10	1.10	1.05	1.05	1.00	1.00	1.00	1.00	.95	.90	.90	.90	.90	.85	.85	.85	.80	.80

17.00	17.25	17.50	17.75	18.00	18.25	18.50	18.75	19.00	19.25	19.50	19.75	20.00	.00	.00
1.10	1.05	1.00	1.00	1.00	.95	.95	.95	.95	.95	.90	.90	.90	4.88	4.04
.80	.80	.80	.80	.80	.80	.80	.80	.80	.80	.80	.75	.75	3.38	.76
.80	.80	.80	.80	.80	.75	.75	.75	.75	.75	.75	.70	.70	3.88	.00

PRINT C32

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
18.50	18.40	18.40	18.30	18.20	18.20	17.90	17.70	17.30	16.80	15.90	14.80	13.40	12.00	10.50	9.20	7.90	6.80	5.90	5.10
19.00	19.00	18.80	18.60	18.50	18.30	18.10	17.80	17.20	16.40	15.20	13.60	12.10	10.80	9.20	7.80	6.70	5.80	5.10	4.40
18.60	18.40	18.20	18.20	18.10	17.90	17.60	17.20	16.60	15.70	14.50	12.90	11.40	9.80	8.40	7.00	5.90	5.00	4.20	3.60

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
4.50	4.00	3.50	3.30	3.00	2.70	2.50	2.40	2.20	2.10	2.00	1.90	1.85	1.80	1.70	1.65	1.60	1.55	1.50	1.45
3.90	3.50	3.00	2.80	2.60	2.40	2.30	2.10	2.00	1.90	1.80	1.75	1.70	1.60	1.55	1.50	1.45	1.40	1.40	1.35
3.20	2.70	2.50	2.20	2.00	1.90	1.80	1.60	1.50	1.50	1.40	1.30	1.25	1.20	1.20	1.10	1.10	1.05	1.00	1.00

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	.00	.00
1.40	1.40	1.35	1.30	1.30	1.30	1.25	1.25	1.20	5.38	4.88
1.30	1.30	1.25	1.20	1.20	1.20	1.15	1.15	1.00	4.63	.43
1.00	.95	.90	.90	.90	.85	.85	.85	.80	4.63	.00

PRINT C33

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
18.60	18.50	18.40	18.10	18.00	17.90	17.70	17.10	16.40	15.30	13.90	12.20	10.50	8.80	7.40	6.20	5.30	4.50	3.90	3.40
18.70	18.50	18.40	18.30	18.20	18.00	17.50	17.00	16.10	14.70	13.10	11.10	9.20	7.60	6.20	5.00	4.20	3.60	3.10	2.70
18.70	18.50	18.40	18.30	18.20	18.00	17.70	17.20	16.10	14.90	13.20	11.10	9.90	8.20	6.80	5.60	4.60	3.90	3.40	2.90

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
3.00	2.80	2.50	2.20	2.10	2.00	1.90	1.80	1.70	1.60	1.55	1.50	1.45	1.40	1.35	1.30	1.30	1.25	1.20	1.20
2.40	2.20	2.00	1.80	1.60	1.55	1.50	1.40	1.40	1.30	1.20	1.15	1.15	1.10	1.10	1.05	1.00	1.00	1.00	.95
2.70	2.40	2.20	2.10	1.90	1.80	1.70	1.60	1.50	1.40	1.40	1.35	1.30	1.25	1.20	1.20	1.10	1.10	1.05	1.05

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	.00	.00
1.20	1.15	1.10	1.10	1.10	1.10	1.05	1.05	1.00	4.63	4.63
.90	.90	.90	.90	.90	.85	.85	.80	.80	4.63	.00
1.00	1.00	1.00	1.00	1.00	.95	.95	.95	.90	4.63	.00

PRINT C34

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
18.60	18.50	18.40	18.30	18.20	17.80	17.30	16.40	15.30	13.30	11.20	9.30	7.70	6.20	5.10	4.30	3.60	3.20	2.80	2.40
18.80	18.70	118.40	18.30	18.00	17.50	16.90	15.70	14.20	12.10	10.00	7.90	6.30	5.00	4.10	3.40	2.90	2.50	2.30	2.10
18.80	18.40	18.40	18.10	17.60	17.00	16.00	14.20	11.90	9.80	7.70	6.10	4.70	3.60	3.00	2.50	2.20	2.00	1.80	1.60

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
2.30	2.10	1.90	1.80	1.70	1.60	1.50	1.50	1.40	1.35	1.30	1.25	1.20	1.15	1.10	1.10	1.10	1.05	1.05	1.00
1.85	1.70	1.60	1.50	1.40	1.35	1.30	1.20	1.10	1.10	1.05	1.00	1.00	.95	.95	.95	.95	.90	.90	.90
1.40	1.30	1.20	1.10	1.10	1.05	1.00	.95	.90	.85	.80	.80	.75	.75	.75	.70	.70	.70	.70	.70

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	.00	.00
1.00	1.00	.95	.95	.95	.90	.90	.90	.90	4.38	3.63
.85	.85	.80	.80	.80	.80	.80	.80	.80	2.63	.90
.70	.70	.65	.65	.65	.65	.60	.60	.60	3.88	.00

PRINT C35

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
19.30	19.10	19.00	18.70	18.60	17.80	16.70	14.90	12.30	10.00	7.70	6.20	4.90	4.00	3.40	2.90	2.60	2.30	2.10	1.90
18.90	18.80	18.50	18.20	17.70	17.10	15.60	13.60	10.80	8.40	6.40	5.00	4.00	3.20	2.70	2.30	2.00	1.80	1.60	1.50
18.80	18.80	18.60	18.50	18.10	17.60	16.30	14.40	12.10	9.70	7.60	5.90	4.70	3.80	3.10	2.80	2.50	2.20	2.00	1.85

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
1.80	1.65	1.60	1.50	1.40	1.35	1.30	1.25	1.20	1.15	1.10	1.10	1.05	1.05	1.00	1.00	1.00	.95	.95	.90
1.40	1.30	.12	1.15	1.10	1.00	1.00	.95	.90	.85	.80	.80	.80	.80	.75	.75	.75	.70	.70	.70
1.70	1.60	1.50	1.40	1.35	1.30	1.25	1.20	1.15	1.10	1.10	1.05	1.00	.95	.95	.95	.90	.90	.90	.90

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	.00	.00
.90	.90	.90	.85	.85	.85	.85	.80	.80	3.88	3.96
.70	.70	.65	.65	.65	.60	.60	.60	.60	3.88	.14
.85	.85	.85	.85	.80	.80	.80	.80	.80	4.13	.00

PRINT C36

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
19.10	18.90	18.70	18.30	17.80	16.10	14.50	11.70	8.80	6.70	5.10	4.00	3.20	2.80	2.40	2.10	1.90	1.80	1.60	1.50
18.70	1.86	18.10	17.70	16.80	15.30	12.90	9.90	7.00	5.30	4.00	3.10	2.50	2.10	1.80	1.60	1.40	1.30	1.20	1.10
19.50	19.40	19.10	18.90	18.40	17.50	15.60	13.20	10.40	7.80	6.00	4.60	3.70	3.00	2.60	2.40	2.10	1.95	1.80	1.60

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
1.45	1.35	1.30	1.20	1.15	1.10	1.10	1.05	1.00	.95	.95	.95	.90	.90	.85	.85	.85	.80	.80	.80
1.00	1.00	.95	.90	.85	.80	.80	.75	.70	.70	.65	.65	.65	.60	.60	.60	.60	.60	.60	.60
1.50	.14	1.35	1.30	1.25	1.20	1.15	1.10	1.05	1.05	1.00	1.00	.95	.90	.90	.90	.90	.85	.85	.80

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	.00	.00
.80	.80	.75	.75	.75	.75	.75	.75	.75	3.88	3.29
.60	.60	.55	.55	.55	.55	.55	.55	.55	2.13	1.01
.80	.80	.80	.80	.80	.75	.75	.75	.75	3.88	.00

PRINT C37

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
19.60	19.50	19.20	19.00	18.40	17.30	14.50	12.50	9.40	7.10	5.50	4.20	3.60	3.00	2.60	2.40	2.20	2.00	1.80	1.70
19.50	19.20	19.00	18.60	17.90	16.20	14.00	11.40	8.30	6.10	4.70	3.60	3.10	2.60	2.40	2.00	1.80	1.60	1.50	1.45
18.90	18.90	18.70	18.30	17.80	16.30	13.30	10.70	7.70	5.50	4.10	3.30	2.60	2.20	1.90	1.70	1.50	1.40	1.30	1.20

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
1.60	1.55	1.45	1.40	1.40	1.25	1.20	1.20	1.15	1.10	1.10	1.00	1.00	1.00	1.00	1.00	.95	.95	.90	.90
1.40	1.30	1.25	1.20	1.15	1.10	1.05	1.00	1.00	.95	.90	.90	.90	.85	.85	.80	.80	.80	.80	.80
1.10	1.10	1.00	1.00	.90	.90	.90	.85	.80	.75	.75	.75	.75	.70	.70	.70	.70	.70	.70	.70

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	.00	.00
.90	.90	.85	.85	.85	.85	.85	.85	.85	3.88	3.71
.75	.75	.75	.70	.70	.70	.70	.70	.70	3.88	.29
.68	.68	.65	.64	.64	.62	.62	.61	.60	3.38	.00

PRINT E32

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
21.35	21.15	20.85	20.45	19.30	17.10	13.40	9.65	6.50	4.65	3.30	2.50	1.95	1.55	1.30	1.05	.95	.85	.80	.70
21.10	21.10	21.00	20.70	20.50	18.65	15.90	13.10	9.90	7.00	5.25	3.90	3.15	2.50	2.10	1.80	1.55	1.40	1.25	1.20
21.10	21.10	21.05	20.80	19.80	17.60	13.90	10.45	7.70	5.65	4.30	3.35	2.70	2.35	2.00	1.80	1.60	1.45	1.30	1.25
21.40	21.40	21.40	21.30	20.55	18.90	16.20	12.90	9.80	7.30	5.60	4.45	3.70	3.10	2.65	2.35	2.05	1.85	1.70	1.60

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	.00	.00
.65	.60	.55	.55	.50	.50	.50	.45	.45	.45	.45	.45	.45	3.63	3.63
1.10	.95	.90	.85	.85	.80	.80	.80	.80	.80	.80	.80	.80	3.88	.20
1.20	1.10	1.10	1.05	1.00	1.00	.95	.90	.90	.90	.85	.80	.80	3.38	.00
1.50	1.45	1.35	1.30	1.30	1.25	1.20	1.15	1.15	1.10	1.10	1.10	1.00	3.63	.00

PRINT E33

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
21.95	21.80	21.55	21.20	20.30	18.20	15.10	11.20	8.15	5.90	4.20	3.45	2.80	2.35	2.00	1.70	1.55	1.40	1.30	1.20
21.45	21.45	21.40	21.35	20.70	19.00	15.95	12.65	9.55	7.20	5.50	4.40	3.60	3.00	2.50	2.20	2.00	1.80	1.60	1.50
20.85	20.85	20.80	20.60	19.95	18.40	15.30	11.90	8.90	6.60	4.80	4.00	3.30	2.75	2.30	2.05	1.80	1.65	1.50	1.40
21.15	20.95	20.80	20.60	20.05	18.40	15.50	12.05	9.00	6.65	5.10	4.00	3.30	2.70	2.35	2.05	1.85	1.60	1.50	1.40

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	.00	.00
1.10	1.05	1.00	.95	.95	.90	.85	.80	.80	.80	.80	.80	.80	3.63	3.63
1.40	1.30	1.30	1.25	1.20	1.15	1.10	1.10	1.05	1.00	1.00	1.00	1.00	3.63	.00
1.30	1.30	1.20	1.15	1.10	1.05	1.05	1.00	1.00	.95	.90	.90	.90	3.63	.00
1.30	1.25	1.20	1.15	1.10	1.05	1.00	1.00	1.00	.95	.95	.95	.90	3.63	.00

PRINT E34

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
21.10	20.90	20.80	20.40	19.40	17.20	13.70	10.50	7.75	5.60	4.30	3.40	2.90	2.40	2.10	1.85	1.70	1.55	1.45	1.35
20.80	20.70	20.60	20.35	19.55	17.55	14.50	11.15	8.40	6.30	4.90	4.00	3.35	2.80	2.50	2.20	2.00	1.85	1.70	1.60
21.20	21.10	20.80	20.15	18.30	15.10	10.80	8.70	6.15	4.50	3.60	2.90	2.50	2.10	1.90	1.65	1.50	1.35	1.30	1.25

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	.00	.00
1.30	1.20	1.20	1.15	1.10	1.05	1.00	1.00	1.00	.95	.95	.95	.95	3.38	3.46
1.60	1.55	1.45	1.40	1.35	1.30	1.30	1.25	1.20	1.20	1.15	1.15	1.15	3.63	.14
1.20	1.20	1.15	1.05	1.00	1.00	.95	.95	.95	.90	.90	.90	.90	3.38	.00

PRINT E35

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
20.80	20.75	20.60	20.05	18.50	15.75	11.05	7.60	5.00	3.85	2.95	2.85	1.90	1.60	1.40	1.30	1.20	1.10	1.05	1.00
21.65	21.40	21.30	20.95	19.70	16.80	12.80	9.30	6.60	4.80	3.70	2.95	2.40	2.10	1.80	1.65	1.50	1.35	1.30	1.25
21.90	21.70	21.40	20.70	19.10	15.30	11.80	8.40	6.00	4.50	3.55	2.90	2.35	2.00	1.80	1.65	1.50	1.35	1.30	1.20

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	.00	.00
.90	.90	.85	.85	.80	.75	.75	.75	.75	.75	.70	.70	.70	3.38	3.29
1.20	1.10	1.10	1.05	1.00	1.00	.95	.95	.90	.90	.85	.85	.85	3.38	.14
1.15	1.10	1.05	1.00	1.00	.95	.95	.90	.90	.90	.90	.90	.90	3.13	.00

PRINT E36

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
21.30	21.10	20.80	19.50	16.70	11.75	7.55	4.95	3.50	2.55	1.95	1.60	1.35	1.20	1.05	1.00	.90	.85	.80	.75
21.60	21.20	20.90	19.85	16.00	11.35	7.45	5.00	3.50	2.60	2.00	1.60	1.40	1.20	1.10	1.05	.95	.85	.85	.80
21.50	21.40	21.25	20.20	15.65	11.75	7.70	5.05	3.55	2.65	2.10	1.70	1.40	1.25	1.15	1.05	1.00	.90	.85	.85

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	.00	.00
.75	.70	.70	.70	.70	.70	.70	.65	.65	.60	.60	.60	.60	3.13	3.04
.80	.75	.70	.70	.70	.65	.65	.65	.65	.60	.60	.60	.60	3.13	.14
.80	.80	.80	.80	.75	.70	.70	.70	.70	.70	.70	.70	.70	2.88	.00

PRINT E37

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
21.90	21.55	21.20	20.00	16.45	11.60	7.80	5.40	3.80	3.55	2.50	2.10	1.85	1.60	1.50	1.35	1.30	1.20	1.15	1.15
21.25	21.05	21.00	19.65	16.30	12.05	7.20	5.20	3.80	2.90	2.35	1.95	1.70	1.45	1.40	1.30	1.20	1.10	1.10	1.05
21.30	21.05	20.65	18.50	13.80	8.90	5.65	3.60	2.70	2.00	1.55	1.30	1.20	1.05	1.00	.90	.85	.80	.75	.70

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	.00	.00
1.10	1.10	1.10	1.00	1.00	1.00	1.00	.95	.95	.95	.90	.90	.90	3.13	3.21
1.00	1.00	.95	.95	.95	.90	.90	.90	.90	.90	.90	.85	.85	3.38	.14
.70	.65	.65	.65	.65	.65	.60	.60	.60	.60	.60	.60	.60	3.13	.00

PRINT I32

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
19.05	17.85	13.85	8.20	5.20	3.20	2.20	1.65	1.80	1.05	.90	.80	.70	.60	.60	.50	.50	.45	.45	.40
19.00	18.45	14.75	9.40	6.00	4.00	3.85	2.15	1.80	1.35	1.20	1.00	.90	.80	.70	.60	.60	.55	.50	.50
20.40	19.90	16.50	10.70	6.95	4.50	3.05	2.15	1.65	1.30	1.10	.90	.80	.70	.70	.60	.50	.50	.45	.45

7.00	7.25	7.50	.00	.00
.40	.40	.40	2.63	2.63
.50	.50	.50	2.63	.00
.45	.45	.45	2.63	.00

PRINT I33

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
21.10	16.20	9.30	5.00	3.10	2.10	1.60	1.20	1.00	.90	.80	.70	.60	.55	.55	.50	.50	.45	.45	.40
21.10	16.20	9.30	5.00	3.10	2.10	1.60	1.20	1.00	.90	.80	.70	.60	.55	.55	.50	.50	.45	.45	.40
21.35	20.80	17.70	11.70	7.20	4.70	3.20	2.30	1.80	1.40	1.20	1.00	.90	.80	.75	.65	.60	.55	.50	.50

7.00	7.25	7.50	.00	.00
.40	.40	.40	2.38	2.46
.40	.40	.40	2.38	.14
.50	.50	.50	2.63	.00

[illegible]

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
21.10	17.80	11.35	6.10	3.30	2.20	1.60	1.20	1.00	.85	.70	.60	.50	.50	.45	.40	.40	.35	.35	.35
21.40	19.05	12.10	6.85	4.30	2.85	2.10	1.60	1.30	1.10	.95	.85	.70	.65	.60	.60	.55	.50	.50	.50
21.15	20.30	16.85	11.05	6.90	4.35	3.05	2.25	1.80	1.45	1.20	1.00	.90	.80	.75	.65	.60	.60	.55	.55

7.00	7.25	7.50	.00	.00
.35	.35	.35	2.38	2.46
.45	.45	.45	2.38	.14
.50	.50	.50	2.63	.00

PRINT I35

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
20.95	20.50	18.90	14.20	8.50	6.00	4.10	3.00	2.30	1.80	1.50	1.25	1.05	.95	.90	.80	.75	.70	.65	.60
21.90	21.55	18.80	13.45	8.80	6.80	4.25	3.25	2.55	2.05	1.70	1.50	1.30	1.20	1.05	.95	.90	.85	.80	.80
21.05	20.35	16.70	10.50	6.50	4.00	3.00	2.25	1.80	1.45	1.25	1.10	1.00	.90	.80	.70	.70	.65	.60	.60

7.00	7.25	7.50	.00	.00
.60	.55	.55	2.88	2.71
.70	.70	.65	2.63	.14
.55	.50	.50	2.63	.00

PRINT I36

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
21.40	19.35	13.50	8.35	5.30	3.40	2.75	2.05	1.70	1.40	1.20	1.05	1.00	.85	.80	.75	.70	.70	.65	.65
21.00	16.40	8.10	4.00	2.45	1.50	1.15	.85	.75	.60	.55	.45	.45	.40	.40	.35	.35	.30	.30	.30
21.15	19.85	14.20	8.00	4.70	3.05	2.15	1.55	1.30	1.00	.90	.75	.70	.65	.60	.55	.50	.50	.45	.45

7.00	7.25	7.50	.00	.00
.60	.60	.60	2.38	2.46
.30	.30	.30	2.38	.14
.40	.40	.40	2.63	.00

PRINT I37

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
21.80	18.40	11.00	6.00	3.55	2.45	1.75	1.35	1.20	1.00	.85	.70	.70	.65	.65	.60	.55	.50	.50	.45
21.80	19.90	12.00	6.15	3.60	2.25	1.60	1.20	1.00	.80	.70	.60	.60	.55	.50	.45	.45	.40	.40	.40
21.70	18.80	10.05	5.30	2.95	1.90	1.40	1.05	.90	.80	.70	.60	.50	.45	.45	.45	.40	.40	.40	.35

7.00	7.25	7.50	.00	.00
.45	.40	.40	2.38	2.38
.35	.35	.35	2.38	.00
.35	.35	.35	2.38	.00

PRINT 032

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
18.55	18.35	18.20	18.10	18.00	17.95	17.80	17.60	17.40	17.00	16.45	15.75	14.60	13.25	11.50	9.70	8.05	6.55	5.20	4.35
18.10	18.10	18.10	18.00	17.80	17.70	17.60	17.30	17.10	16.65	16.05	15.40	14.10	12.65	11.00	9.20	7.50	6.20	4.90	4.00
18.50	18.50	18.30	18.20	18.10	18.10	18.10	17.95	17.75	17.45	16.75	15.15	14.50	12.70	10.80	8.90	7.20	5.50	4.70	3.60
18.30	18.30	18.30	18.30	18.30	18.30	18.25	18.20	18.20	18.10	17.80	17.35	16.80	15.80	14.50	12.90	11.40	9.55	7.95	6.45
18.50	18.50	18.50	18.45	18.45	18.40	18.30	18.00	17.70	17.30	16.70	15.65	14.25	12.50	10.40	8.50	6.65	5.25	4.15	3.30

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
3.30	2.80	2.40	2.00	1.70	1.45	1.35	1.15	1.05	.90	.90	.85	.80	.75	.70	.70	.70	.70	.65	.65
3.80	2.70	2.25	1.80	1.65	1.40	1.25	1.10	1.00	.95	.90	.85	.80	.80	.75	.75	.70	.70	.70	.70
3.00	2.45	2.05	1.70	1.45	1.30	1.15	1.00	.95	.90	.80	.80	.80	.75	.70	.70	.70	.70	.70	.70
5.95	4.50	3.80	3.20	2.65	2.25	2.00	1.90	1.55	1.35	1.30	1.25	1.10	1.05	1.00	1.00	.90	.90	.90	.90
2.70	2.20	1.80	1.55	1.30	1.15	1.05	.95	.90	.80	.75	.70	.70	.70	.70	.70	.70	.70	.70	.70

.00	.00
5.63	5.63
5.63	.31
5.38	.00
6.13	.00
5.38	.00

PRINT 033

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
19.30	19.30	19.30	19.25	18.80	18.65	18.55	18.00	17.50	16.20	14.80	13.00	10.70	8.40	6.40	4.90	3.70	2.90	2.20	1.75
19.10	19.10	19.00	19.00	18.80	18.10	17.90	17.35	17.25	15.70	13.50	10.60	7.90	5.70	4.15	3.00	2.25	1.65	1.40	1.15
18.60	18.60	18.60	18.60	18.60	18.60	18.50	18.20	17.60	16.50	15.00	12.85	10.50	8.00	6.10	4.50	3.40	2.60	2.10	1.65

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	.00	.00
1.45	1.20	1.10	.90	.80	.70	.65	.60	4.88	4.88
.95	.85	.80	.75	.70	.70	.70	.70	4.63	.25
1.40	1.20	1.05	1.00	.95	.90	.85	.85	5.13	.00

PRINT 034

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
19.00	19.00	19.00	19.00	18.80	18.50	18.30	18.15	17.50	16.50	14.80	12.80	10.30	8.15	6.15	4.80	3.60	2.90	2.30	1.90
19.00	19.00	19.00	18.90	18.65	18.65	18.45	18.10	17.20	16.20	13.70	11.30	8.30	6.50	4.50	3.50	2.50	2.00	1.60	1.30
18.90	18.90	18.90	18.90	18.80	18.70	18.30	18.10	17.10	16.65	14.60	12.70	9.80	7.80	5.60	4.40	3.20	2.50	1.90	1.60
18.80	18.80	18.80	18.60	18.50	18.30	17.90	17.20	15.80	13.40	11.30	8.80	6.65	5.00	3.75	2.80	2.70	1.80	1.40	1.30

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	.00	.00
1.50	1.40	1.20	1.10	.90	.90	.90	.90	4.88	4.81
1.10	.90	.80	.80	.75	.70	.70	.70	4.88	.13
1.30	1.15	1.00	.90	.85	.80	.80	.80	4.88	.00
1.10	1.00	.90	.90	.85	.80	.80	.80	4.63	.00

PRINT 035

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
18.80	18.70	18.60	18.50	18.50	18.30	17.90	16.25	15.65	13.60	10.80	8.00	5.70	4.10	3.00	2.20	1.70	1.40	1.20	1.00
19.30	19.30	19.20	19.20	19.10	18.80	18.40	17.50	15.80	13.50	10.70	7.90	5.60	3.90	2.90	2.20	1.70	1.40	1.35	1.10
18.50	18.50	18.50	18.50	18.40	17.90	17.30	15.60	13.60	10.20	7.20	4.90	3.20	2.10	1.75	1.25	1.00	.90	.70	.65

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	.00	.00
.90	.80	.80	.70	.70	.65	.65	.65	4.38	4.29
1.00	1.00	1.00	.90	.90	.90	.90	.90	4.38	.14
.60	.60	.55	.50	.50	.50	.50	.50	4.13	.00

PRINT 036

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
18.90	18.90	18.90	18.90	18.80	18.40	17.55	15.90	13.35	10.80	7.70	5.70	3.70	2.55	1.75	1.40	1.10	.90	.80	.65
18.90	18.90	18.70	18.60	18.40	18.00	17.00	15.70	13.10	9.95	7.10	4.90	3.30	2.40	1.80	1.40	1.10	.90	.80	.75
19.20	19.10	19.00	18.65	18.30	17.80	16.10	14.30	10.70	7.30	4.35	3.20	2.15	1.50	1.15	.95	.75	.70	.60	.60

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	.00	.00
.60	.55	.50	.50	.50	.50	.50	.50	4.38	4.13
.70	.70	.65	.60	.60	.60	.60	.60	4.13	.25
.55	.50	.50	.50	.50	.50	.50	.50	3.88	.00

PRINT 037

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
18.90	18.70	18.60	18.30	17.60	16.90	15.30	12.40	8.70	5.70	3.60	2.40	1.70	1.20	.90	.75	.65	.55	.50	.50
19.10	19.00	18.70	18.60	18.20	17.20	14.20	11.60	7.90	5.10	3.30	2.30	1.60	1.20	1.00	.90	.75	.65	.60	.60
19.00	18.90	18.80	18.80	18.50	17.90	16.50	13.90	9.60	5.90	3.70	2.40	1.70	1.30	1.00	.90	.80	.80	.80	.80

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	.00	.00
.50	.45	.45	.45	.45	.45	.45	.45	3.88	3.88
.55	.55	.55	.55	.55	.55	.55	.55	3.88	.00
.80	.80	.80	.80	.80	.80	.80	.80	3.88	.00

PRINT P32

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
18.80	18.80	18.80	18.80	18.80	18.80	18.70	18.65	18.65	18.60	18.55	18.30	17.80	17.35	16.20	15.40	14.60	13.50	12.40	11.40
18.90	18.90	18.90	18.90	18.80	18.60	18.60	18.55	18.50	18.50	18.50	18.40	18.20	17.85	17.15	16.50	15.60	14.55	13.60	12.40
18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.90	18.75	18.40	18.20	17.55	16.90	16.00	14.75	13.85	12.75
19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	18.90	18.85	18.60	18.40	18.00	17.50	16.70	15.80	14.80	13.60	12.50

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
10.40	9.50	8.70	7.90	7.25	6.65	6.15	5.70	5.40	5.00	4.65	4.40	4.20	3.90	3.80	3.60	3.50	3.35	3.30	3.20
11.40	10.50	9.60	8.80	8.00	7.30	6.75	6.25	5.60	5.30	5.00	4.70	4.40	4.15	3.90	3.80	3.60	3.50	3.35	3.20
11.60	10.70	9.90	9.10	8.30	7.55	7.00	6.50	6.00	5.65	5.25	4.90	4.70	4.45	4.25	4.00	3.85	3.80	3.65	3.50
11.25	10.30	9.30	8.50	7.70	7.00	6.40	5.90	5.50	5.10	4.80	4.45	4.20	4.00	3.80	3.60	3.40	3.30	3.20	3.10

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	.00	.00
3.10	3.00	2.95	2.90	2.85	2.80	2.80	2.80	2.75	2.75	2.75	2.75	2.75	2.75	2.70	5.38	6.25
3.10	3.00	2.95	2.90	2.85	2.80	2.80	2.75	2.70	2.65	2.65	2.60	2.60	2.60	2.60	6.63	.66
3.45	3.30	3.25	3.15	3.10	3.05	3.00	3.00	2.95	2.90	2.85	2.85	2.85	2.85	2.80	6.13	.00
3.00	2.90	2.85	2.80	2.75	2.75	2.70	2.70	2.70	2.70	2.60	2.60	2.60	2.60	2.60	6.88	.00

PRINT P33

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.20	18.65	17.70	16.70	15.65	14.60	13.40	12.10
19.85	19.85	19.85	19.85	19.85	19.85	19.85	19.85	19.85	19.85	19.70	19.05	18.30	17.05	15.80	14.50	13.20	11.90	10.70	9.60
19.55	19.55	19.55	19.55	19.40	19.40	19.40	19.40	19.30	19.30	19.15	19.00	18.80	18.10	17.60	16.80	15.50	14.70	13.15	12.10

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
11.20	10.20	9.20	8.35	7.70	7.00	6.40	6.35	5.45	5.10	4.70	4.50	4.25	4.05	3.90	3.70	3.55	3.40	3.35	3.25
8.65	7.80	7.10	6.40	5.80	5.30	4.90	4.50	4.20	3.90	3.65	3.45	3.25	3.10	3.00	2.90	2.80	2.75	2.70	2.65
11.00	10.05	9.15	8.30	7.90	6.80	6.20	5.70	5.30	4.90	4.60	4.30	4.10	3.90	3.65	3.50	3.40	3.30	3.15	3.00

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	.00	.00
3.20	3.10	3.05	3.00	2.95	2.90	2.90	2.85	2.85	2.85	2.80	2.80	2.80	2.80	2.80	6.63	6.21
2.60	2.55	2.50	2.50	2.50	2.45	2.45	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	5.63	.52
3.00	2.90	2.85	2.80	2.75	2.70	2.70	2.65	2.60	2.60	2.60	2.60	2.60	2.60	2.55	6.38	.00

PRINT P34

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
18.45	18.45	18.45	18.45	18.45	18.45	18.45	18.30	18.30	18.05	17.80	17.25	16.50	15.30	14.25	13.00	11.80	10.80	9.50	8.50
18.60	18.60	18.60	18.60	18.60	18.60	18.60	18.60	18.60	18.60	18.25	18.00	17.40	16.75	15.60	14.50	13.20	11.90	10.55	9.45
19.05	19.05	19.05	19.05	19.05	19.05	19.05	19.05	19.05	18.90	18.70	18.00	17.30	16.15	15.05	13.85	12.40	11.00	9.95	8.85

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
7.70	6.80	6.30	5.70	5.25	4.80	4.50	4.10	3.80	3.70	3.50	3.30	3.10	2.95	2.85	2.80	2.75	2.70	2.65	2.60
8.40	7.50	6.65	6.00	5.40	4.90	4.50	4.10	3.80	3.60	3.40	3.10	3.00	2.85	2.70	2.60	2.50	2.45	2.40	2.35
7.90	7.00	6.50	5.70	5.20	4.75	4.45	4.10	3.80	3.60	3.40	3.25	3.10	3.00	2.85	2.75	2.70	2.60	2.55	2.55

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	.00	.00
2.55	2.55	2.50	2.50	2.45	2.45	2.45	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	6.38	6.21
2.30	2.25	2.20	2.15	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.05	2.05	2.05	6.38	.29
2.50	2.40	2.40	2.35	2.35	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	5.88	.00

PRINT P35

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
19.10	19.10	19.10	19.10	19.10	19.10	19.00	19.00	19.00	18.90	18.60	18.15	17.40	16.60	15.40	14.00	12.60	12.35	10.00	9.00
19.35	19.35	19.25	19.25	19.20	19.10	19.10	19.00	19.00	18.80	18.40	17.70	16.75	15.20	14.00	12.50	11.10	9.85	8.70	7.80
19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.40	19.35	19.30	18.80	18.00	16.80	15.40	14.00	12.50	11.10	9.80	8.60	7.60

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
8.00	7.10	6.85	5.70	5.50	4.70	4.20	4.00	3.75	3.45	3.35	3.15	3.00	2.90	2.80	2.70	2.60	2.60	2.55	2.45
6.95	6.70	5.65	5.10	4.70	4.35	4.10	3.80	3.60	3.40	3.30	3.20	3.00	2.90	2.90	2.80	2.70	2.65	2.65	2.60
6.85	6.15	5.50	5.00	4.50	4.15	3.90	3.50	3.40	3.20	3.00	2.90	2.80	2.70	2.60	2.50	2.45	2.45	2.40	2.40

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	.00	.00
2.40	2.40	2.40	2.35	2.35	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	6.38	5.71
2.60	2.60	2.60	2.55	2.55	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	5.13	.63
2.40	2.35	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	5.63	.00

PRINT P36

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
19.60	19.60	19.60	19.60	19.60	19.60	19.55	19.40	18.40	18.05	17.55	16.80	15.70	14.30	12.90	11.00	10.25	9.00	8.00	7.10
20.35	20.35	20.35	20.35	20.35	20.35	20.35	20.35	20.35	20.10	19.50	18.40	17.40	16.00	14.70	13.10	11.35	10.00	8.90	7.70
20.65	20.65	20.65	20.60	20.60	20.50	20.30	19.90	19.10	19.10	18.60	17.55	16.20	14.40	13.00	11.20	9.90	8.60	7.60	6.70
20.10	20.10	20.10	20.10	20.10	20.10	19.90	19.70	19.30	18.85	18.00	16.15	15.15	13.40	11.60	9.80	8.70	7.55	6.55	5.80

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
6.20	5.60	5.00	4.60	4.20	3.90	3.60	3.40	3.20	3.00	2.90	2.80	2.70	2.60	2.50	2.50	2.50	2.40	2.40	2.35
6.90	6.15	5.50	4.95	4.60	4.15	3.95	3.60	3.45	3.30	3.20	3.10	3.00	2.90	2.80	2.80	2.75	2.70	2.65	2.60
5.80	5.20	4.70	4.20	3.80	3.50	3.30	3.15	2.90	2.80	2.70	2.55	2.50	2.50	2.40	2.30	2.30	2.30	2.30	2.30
5.10	4.50	4.10	3.65	3.50	3.00	2.80	2.65	2.50	2.45	2.40	2.30	2.30	2.25	2.20	2.20	2.15	2.10	2.10	2.10

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	.00	.00
2.35	2.35	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	5.63	5.31
2.60	2.60	2.55	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	5.88	.55
2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.15	2.15	2.15	2.15	2.15	2.15	2.15	5.13	.00
2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	4.63	.00

PRINT P37

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75
19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.30	19.20	18.70	17.75	16.60	15.05	13.20	11.50	10.00	8.70	7.50	6.55	5.65
19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.30	19.10	18.40	17.10	15.40	13.60	11.80	10.10	8.70	7.40	6.30	5.70	4.95
19.80	19.80	19.70	19.70	19.70	19.70	19.70	19.50	19.45	18.95	18.20	17.10	15.40	13.50	12.00	10.30	8.90	7.70	6.70	5.85

7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75
5.00	4.50	4.00	3.70	3.40	3.15	2.85	2.80	2.60	2.50	2.45	2.40	2.30	2.20	2.20	2.20	2.20	2.20	2.20	2.20
4.40	4.00	3.70	3.45	3.15	2.95	2.80	2.70	2.60	2.50	2.40	2.35	2.30	2.30	2.25	2.20	2.20	2.20	2.20	2.20
5.05	4.50	4.10	3.70	3.40	3.15	2.95	2.80	2.65	2.50	2.40	2.35	2.30	2.20	2.20	2.20	2.15	2.10	2.10	1.05

12.00	12.25	12.50	12.75	13.00	13.25	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	.00	.00
2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	5.13	5.04
2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	4.88	.14
1.05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5.13	.00

PRINT R32

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	.00	.00
17.00	16.40	15.55	14.65	13.70	12.35	10.60	8.00	5.05	2.70	1.80	.55	.50	.50	.50	.50	.50	.50	.50	3.88	4.13
18.50	17.80	17.40	16.60	15.90	15.10	14.10	12.20	10.80	8.20	5.50	3.20	1.60	.80	.60	.55	.50	.50	.50	4.38	.25
17.50	16.75	15.90	15.30	14.55	13.60	12.20	10.60	8.50	5.85	3.55	2.05	.90	.50	.45	.45	.40	.40	.40	4.13	.00

PRINT R33

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	.00	.00
16.85	15.75	14.70	13.75	12.70	11.25	9.10	6.30	3.50	1.40	.70	.35	.30	.30	.30	.30	.30	.30	.30	3.63	3.79
17.80	17.00	16.35	15.65	14.75	13.60	12.10	9.65	6.45	3.45	1.75	.65	.50	.45	.45	.45	.45	.45	.45	3.88	.14
19.00	18.30	17.55	16.95	16.30	15.10	13.10	10.45	7.15	4.00	1.60	.65	.60	.60	.60	.60	.60	.60	.60	3.88	.00

PRINT R34

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	.00	.00
16.80	15.80	14.95	13.85	12.50	10.30	6.80	4.00	1.70	.55	.40	.40	.40	.40	.40	.40	.40	.40	.40	3.38	3.54
16.80	16.15	15.10	14.25	13.25	11.80	9.40	6.20	3.00	1.10	.50	.45	.45	.45	.45	.45	.45	.45	.45	3.63	.14
15.00	14.25	13.60	12.80	11.60	9.85	7.30	3.95	2.00	.60	.40	.40	.40	.40	.40	.40	.40	.40	.40	3.63	.00

PRINT R35

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50	.00	.00
15.80	15.05	14.35	13.35	11.90	9.60	6.15	2.80	.90	.45	.45	.40	.40	.40	.40	.40	.40	.40	.40	3.38	3.21
16.00	14.70	13.50	11.90	9.55	5.70	2.60	.80	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	3.13	.14
16.05	14.80	13.55	12.05	9.50	5.75	2.50	.60	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	3.13	.00

PRINT R36

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	.00	.00
18.90	18.05	16.85	15.60	13.35	9.25	4.50	1.35	.55	.50	.50	.50	.50	.50	.50	.50	.50	3.38	3.21
15.10	13.95	12.95	11.45	8.90	5.35	2.35	.55	.30	.30	.30	.30	.30	.30	.30	.30	.30	3.13	.14
16.80	15.50	14.45	12.85	10.40	6.15	2.70	.70	.35	.35	.35	.35	.35	.35	.35	.35	.35	3.13	.00

PRINT R37

2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	.00	.00
17.15	15.75	14.55	12.55	9.10	4.20	1.30	.45	.40	.40	.40	.40	.40	.40	.40	.40	.40	3.13	3.13
18.00	17.40	16.00	13.75	9.50	4.15	.95	.50	.50	.50	.50	.50	.50	.50	.50	.50	.50	3.13	.00
18.10	16.85	15.60	13.70	9.65	4.50	1.15	.55	.55	.55	.55	.55	.55	.55	.55	.55	.55	3.13	.00

APPROVAL SHEET

The thesis submitted by Charles J. Wagener has been read and approved by the following committee:

James L. Sandrik, Ph.D., Advisor
Associate Professor and Chairman, Dental Materials
Loyola School of Dentistry

Leon W. Laub, Ph.D.
Associate Professor, Dental Materials
Loyola School of Dentistry

Joseph M. Gowgiel, D.D.S., Ph.D.
Associate Professor and Chairman, Anatomy
Loyola School of Dentistry

The final copies have been examined by the advisor of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science.

April 21, 1981
Date

James L. Sandrik
Advisor's Signature