ABSTRACT

Evaluation of Homogeneity for Hazardous Waste Solidification by Video Imaging Technique

by

Yi-min Gao

The field of chemical solidification has just begun to mature into an accepted environmental technology for hazardous waste disposal. From the engineering point of view, some key issues still dominate the feasibility and effectiveness of hazardous waste solidification process. "Mixing" is essentially regarded as the most critical element but unfortunately, no evidence has been proposed to prove the homogeneity of the large monolith produced by solidification in order that the effectiveness of the solidification process can be evaluated in satisfactorily short time. The Homogeneity Evaluation by Video Imaging System (HEVIS) proposed in this study is to solve this problem with less time and economic feasibility.

The HEVIS for hazardous waste solidification process employs a fluorescent tracer in conjunction with video imaging analysis. This process provides an important basis for developing a new test method to evaluate the homogeneity of the final products of hazardous waste solidification. This study also shows the feasibility of HEVIS and proposes some recommendations for future applications.

EVALUATION OF HOMOGENEITY FOR HAZARDOUS WASTE SOLIDIFICATION BY VIDEO IMAGING TECHNIQUE

by
Yi-min Gao

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This thesis is dedicated to
Chris and Jessie

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TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 The Purpose of This Study

The field of chemical fixation and solidification, CFS for short, has just begun to mature into an accepted environmental technology [1]. Pushed by regulations that essentially mandate its use for many waste streams, it is becoming a standard unit process in hazardous waste treatment and disposal. Much of the impetus for solidification of hazardous wastes has been provided by the Resource Conservation and Recovery Act (RCRA) of 1976, including the subsequent 1984 amendments (HSWA).

In the past years, more contaminated sites have been discovered and a considerably large amount of hazardous waste is waiting to be treated. Many techniques have been proposed to treat the hazardous wastes during the past few years. Solidification is one of the proposed methods and is regarded as an approved remediation technique for several types of wastes. Solidification has been widely used in low-level radioactive waste treatment since the early 1950's. It has become more popular in application to the disposal of hazardous wastes since the 1980's. Many vendors are studying and developing processes that are directly applicable to hazardous waste treatment.

The advantages of solidification are as follows:

1. Additives and reagents are widely available and relatively inexpensive.
2. The resulting solidified material may require little or no further treatment if proper conditions are maintained.
3. Leaching of contaminants is greatly reduced.

Although these merits are very attractive to engineers, from the engineering point of view, there are still some difficulties with solidification processes. "Mixing" is one of the critical elements for any solidification process. The full benefits of solidification will not be attained unless an appropriate degree of mixing is attained.

Up to now, engineers still assess the mixing procedure by their accumulated experience with solidification processes. No evidence can be proposed to prove the homogeneity of the large monolith in order that the effectiveness of the solidification can be evaluated. Although the Toxicity Characteristic Leaching Procedure (TCLP) test proposed by the U.S. Environmental Protection Agency is widely used by vendors to test the effectiveness of their solidification, no direct evidence can be proposed to verify the "real treatment efficiency" of a large monolith after solidification. The real treatment efficiency can not be known unless the homogeneity of solidification final products can be accurately evaluated. The overall effectiveness of a solidification technique can be obtained by a combination of TCLP tests and an accurate homogeneity evaluation of the solidified product.

The objective of this study is to develop a new test method to evaluate the homogeneity of a solidification process final product. There are two major benefits resulting from this study:

1. The engineers involved in hazardous waste solidification can easily evaluate the degree of mixing of a solidified product after a process is completed. Therefore, better conditions can be attained both to improve the mixing and to assure the effectiveness of the hazardous waste solidification technique.
2. This newly developed test method can be used to accurately assess the homogeneity of a hazardous waste solidification process product after the TCLP tests of samples are completed. The solidification process product is therefore integrally inspected instead of only part of the product.

1.2 The Idea of This Study

In order to evaluate the homogeneities of solidification products, a tracer can be added into the chemical solidifying reagent used in the solidification process. This allows the determination of the dispersion of solidifying reagent, which is the most effective way to measure the degree of mixing in a solidification process. This is important because the solidification efficiency is mainly dominated by the intimacy between the hazardous waste and the solidifying reagent. From an engineering point of view, it is much easier to mix the tracer into the solidifying reagent than the waste. Also, adding tracer into the solidifying reagent would be more economically feasible than adding it into the waste, because less tracer is needed when added into solidifying reagent than when added into the waste. Because the waste to solidifying reagent ratio is about 5:1, poor mixing is much more noticeable if the tracer is added to the solidifying reagent.

In this study, an inorganic high-purity fluorescent powder is used as the tracer in the solidification system. By measuring the dispersion of the fluorescent tracer, the dispersion of the solidifying reagent is known. The solidification product can regarded homogeneous if one of the constituents in the system is verified to be uniform [2].

1.3 Outline of This Study

The objective of this study is to supply a basis for developing a new test method to evaluate the homogeneity of the products of hazardous waste solidification processes. In this study, clean soil is prepared from Ottawa sand and kaolin. Contaminated soil is not used to eliminate possible pollution and/or danger. Type I Portland cement is used as the solidifying reagent, because it is the reagent most widely used in hazardous waste solidification processes and it has very constant chemical and physical properties. A high-purity inorganic fluorescent powder with a particle size smaller than 250 mesh is also used in this study. The fluorescent powder used in this study is from Dr. C. R. Huang's laboratory at NJIT. This fluorescent powder was produced originally for coating a color TV monitor.

All of the mixing factors such as equipment, materials, and procedure except mixing time are fixed firmly in order to be able to duplicate bad-mixing specimens with consistent homogeneities. Before the solidifying reagent is mixed with soil, the fluorescent powder is exactly weighed and added into the solidifying reagent and mixed completely. This solidifying reagent is then further mixed with soil, with varying mixing times to produce the test specimens. Nine samples are taken from each specimen in order to be analyzed by instrumental analysis before the compaction and curing of the solidification product. Pictures of the final products of solidification are taken by video camera and analyzed by a computer imaging technique. The results from both the instrumental and imaging analyses are compared to assess the effectiveness of the computer imaging system.

CHAPTER 2
LITERATURE REVIEW

2.1 Origins

With a few exceptions, the history of the development of CFS systems for general use on waste residues dates only from the 1970's [1]. However, the roots of most present-day commercial CFS systems go back to four primary areas of technology that were practiced long before 1970. These are:

- Radioactive waste solidification and disposal
- Mine backfilling
- Soil stabilization and grouting
- Production of stabilized base courses for road construction

Of these, only radioactive waste treatment is a CFS process in the present sense. The other three applications had other utilitarian purposes, although they frequently used wastes such as flyash in the process. Portland cement or flyash or both were used in mine backfilling, sodium silicate plus setting agents, cement and organic polymerizing systems for grouting and soil stabilization, and lime/flyash for road-base construction.

There are many isolated instances where waste residue generators, especially waste disposal site operators, used cement, flyash, lime, soil, and various combinations of these materials to solidify liquids for disposal in landfills where some stability was required in the fill material.[1] Nearly all of this early work involved a need for solidification only, and rarely, if ever, were leaching or other performance tests conducted or required.

The genesis of most modern-day CFS systems comes from the radioactive waste solidification field that began in the 1950's [1]. Early on, the nuclear industry recognized the need for solidification of radioactive waste in drums and other containers before these wastes could be shipped or buried at government controlled disposal sites in the United States. Much of the liquid waste containing low-level radioactivity was simply absorbed into various mineral sorbents, such as vermiculite, or solidified by making a concrete mixture with very large quantities of Portland cement. In Europe, radioactive wastes were typically solidified in concrete and buried at sea in drums.

The solidification process with cement at that time was not well controlled and was somewhat unpredictable, particularly when constituents that retard the setting of Portland cement were present in the waste streams, as they often were. By the late 1950's, it was realized that the addition of sodium silicate to the Portland cement process often provided better results overall than did other processes [3]. Later, organic polymer processes were also used for radioactive waste solidification [4]. The nuclear industry also experimented with, and used, deep underground disposal of intermediate-level wastes using cement/flyash/clay compositions, pumping the fluid mixtures into fractured shale zones where they solidified and became immobilized [5].

2.2 General Concept of Solidification

Different processes exhibit different setting and curing reactions. Most of the commercial inorganic CFS systems, however, solidify by very similar reactions, which have been thoroughly studied in connection with the Portland cement technology used in making concrete. While the pozzolanic reactions of the processes using flyash and kiln dusts are not identical to those of Portland cement, the general reactions are similar.

One reason for this is presented in an interesting way by Cote [6]. The compositions of most of the primary reagents used in inorganic CFS systems were plotted on a ternary diagram using the three oxide combinations, SiO_2, $CaO + MgO$, and $Al_2O_3 + Fe_2O_3$. All of these reagents have the same active ingredients as far as solidification reactions are concerned. The combinations of these five oxides express the essential composition of any of these materials, even though the actual compounds are not all simple oxides, but more complex silicates and aluminates in many cases.

The important physical factors affecting hazardous waste solidification, as they are related to handling and processing, are as follows:

1. Mixing
2. Particle size and shape
3. Free water content
4. Solids content
5. Specific gravity/density
6. Viscosity
7. Wetting
8. Temperature and humidity

These physical properties dominate the efficiency of a solidification process. The first property --- mixing, is the topic of this study. The other factors are kept constant in order to focus on the mixing problem under constant conditions.

2.3 Performance of Solidification

Solidification keeps gaining stature as a key tool for remediating hazardous wastes. The technique consists of entrapping the wastes within a solid matrix having high structural integrity, which minimizes the risk of escape by leaching. Wastes from a wide range of industries have been solidified. Among these industries are chemicals, electronics manufacture, machinery, metals, paint, wood processing, textiles and petroleum refining. The wastes may consist of liquids, sludges, slurries, or contaminated soils and sediments. Some processes, typically proprietary, are especially suited to handing a particular waste form, such as pumpable sludge [7].

Solidified wastes may still leach, but the rate of contaminant leaching should be very low so that the pollutants will disperse harmlessly into the environment. William Shively et al. [8] verified that the leaching of heavy metals sludges was substantially reduced by solidification and stabilization with Portland cement. Heavy metal concentrations in the 15 extractions of the Toxicity Characteristic Leaching Procedure (TCLP) test were 100 to 10,000 times less than the concentrations predicted for equilibrium solubility of stable hydroxide solids. All samples passed the EPA EP-toxicity test and were not considered hazardous waste.

Although it has been applied mainly to inorganic contaminants, recent experience with organic ones shows promise as well. Solidification technology had first been tested officially by U.S. EPA under the Superfund Innovative Technology Evaluation (SITE) program at in Douglassville, Pennsylvania on October 12, 1987 [9]. According to the EPA assessment, more than 250,000 yd^3 of soil at the facility was contaminated with up to 25 percent by weight of oils and greases. Other contaminants included PCBs, volatiles, semi-volatiles and heavy metals.

The results of the test showed that all metals were reduced to below their detection limits except lead and zinc. In the case of lead and zinc, their values were just above detection, in the 30-50 parts per billion range. This is significant in that the metals, especially lead (24,000 ppm) and zinc (1,600 ppm) were found in significant concentrations. Although PCBs were found in concentrations varying from 50 to 80 ppm at the site, quantification of PCBs in the leachate was not possible after the solidification treatment. All semi-volatile organics were reduced to detection limits of 10 parts per billion in the TCLP leachate of the treated materials [9].

A demonstration of the solidification technique was also conducted under U.S. EPA SITE program in Clackamas, Oregon in March 1989. Waste containing lead, copper, and polychlorinated biphenyls (PCBs) from four different areas of the site was treated. Results showed substantial reduction of leachable lead and copper ranged from 94 to 99 percent by utilizing the TCLP test. Furthermore, PCBs were not found in the leachate from the final products after treatment [10].

CHAPTER 3
BACKGROUND

The background for four principle parts of this study will be discussed in more detail in this chapter. They are: (1)solidification processes; (2)fluorescent tracer; (3)imaging system; (4)data analysis.

3.1 Solidification Processes

This study tests a new method to evaluate the homogeneity of a solidification process final product, and this method must not bring any adverse effect on the performance of hazardous waste solidification.

3.1.1 Solidification Systems

"Solidification" refers to techniques that encapsulate the waste in a monolithic solid of high structural integrity. The encapsulation may be of fine waste particles (microencapsulation) or a large block or a container of wastes (macroencapsulation). Solidification does not necessarily involve a chemical interaction between the wastes and the solidifying reagents, but may mechanically bind the waste into the monolith. Contaminant migration is restricted by vastly decreasing the surface area exposed to leaching and/or by isolating the wastes within an impervious capsule [1]. Solidification technology is applicable to the treatment of hazardous wastes such as fluid wastes, sludges, and contaminated soils. The contaminants may be organics or inorganics.

The factors affecting solidification treatment efficiency can be categorized to two main kinds: physical and chemical factors. The physical factors include particle size and shape of waste, free water content of waste, solids content of waste, density of waste, viscosity of waste, wetting of solidifying agent, temperature and humidity, and mixing. The mixing factor is not only a main concern but also the key issue in this study.

Solidification systems are of two basic types, inorganic or organic, according to the nature of the solidification chemicals used, not the waste composition [11]. Inorganic systems are mostly used for the chemical fixation and solidification of complex wastes and/or mixtures thereof, with the aim of producing a nontoxic, environmentally safe material that can be used as landfill. The processes use inorganic reagents that react with certain waste components; they also react among themselves to form chemically and mechanically stable solids. These systems are based on reactions between binders, catalysts, and setting agents that occur in a controlled manner to produce a solid matrix. The matrix itself, as produced, is often a pseudomineral. This type of structure displays properties of stability, high melting point, and a rigid, friable structure similar to many soils and rocks.

The most important inorganic systems at the moment are:

1. Portland cement
2. Lime/flyash
3. Kiln dust (lime and cement)
4. Portland cement/flyash
5. Portland cement/lime
6. Portland cement/sodium silicate

All of these processes have been used commercially for solidification of water-based waste liquids, sludges, filter cakes, and contaminated soils.

In this study, Type I Portland cement is used as the solidifying reagent not only because it is the most used in industrial solidification systems, but also it has fairly consistent physical and chemical properties which gave a better experimental repeatability. The waste in the solidification system is clean soil which was composed of kaolin clay and Ottawa sand in constant proportion. No contaminant was added into the specimens to prevent possible pollution.

3.1.2 Mixing in Solidification Processes

Mixing is regarded as a critical element of any solidification process. Many people firmly believe that, thanks to our modern equipment, the days of mixing problems are a thing of the past [2]. There is truth in this belief, since under ideal conditions a solidifying reagent can be mixed to some extent with almost any waste, including sticky sludges and filter cakes. There still exists a question about how well the solidifying reagent and waste are mixed. More and more evidence from testing experiments have shown that a solidification system might result in complete failure due to insufficient or inadequate mixing.

While it seems obvious that thorough dispersion of the solidifying reagent in the waste is important, it is also possible to overmix certain systems [1]. Overmixing, either by using the wrong mixer or mixing too long, interferes with the initial gel formation of solidification systems, causing delayed set, slow curing, and even the loss of final physical properties. An extreme example of this is seen in the Portland cement/soluble silicate process. Overmixing irreparably destroys the silica gel structure, preventing the process from working properly at all. This fact corrects a past incorrect concept that the longest mixing time makes the best effects.

On the other hand, it is assumed that very thorough and intimate mixing is required to assure that a reaction will take place and fixation of hazardous constituents will be complete. However, it is known that this does not happen with most in situ techniques and still the end result may be satisfactory, at least from a physical viewpoint [1]. The above facts prove that a rapid and reasonably exact test method is absolutely necessary to inspect the degree of mixing (homogeneity) of the products of solidification processes. The redundant and costly energy used for unnecessary mixing will be able to be saved due to the homogeneity inspection of solidification products. This test method is also needed by governmental regulatory authorities in order to inspect the final products after the completion of solidification processes.

Some researchers and engineers have even proposed a relationship between the degree of mixing and the treatment efficiency of a solidification process, but none of the literature has proposed any way of inspecting or proving the "mixing status" of the solidification products. This study proposes a new method to obtain the "mixing status" of the final products of solidification processes. In this study, all of the mixing conditions including the equipment, and all procedures except mixing time are completely fixed in order to obtain the specimens with various homogeneities. The tested specimens, by this way, have the same mixing degree as long as their mixing times are the same.

3.2 Fluorescent Tracer

3.2.1 Selection of Tracer

The ideal method to determine the homogeneity of a solidification product is by means of its own native chemical or physical properties to prevent additional cost, but this seems very impractical in this study because the wastes and the solidifying reagents in solidification systems are quite varied. The final products from these various solidification systems are thus quite different. For example, the thermal conductivities of the products from the Portland cement and lime solidification systems are too different to be compared based on the same standard. Thus, the determination of the homogeneities of such final products by means of thermal conductivity is not feasible.

The following questions are therefore raised: (1) Is it absolutely necessary to add a tracer into solidification systems in order to determine the homogeneities of process products? (2) If it is necessary, what kind of tracer would be the best choice based on the consideration of both economy and effectiveness? The answer for the first question is yes, because this new test method can then be applied in almost every solidification system. It is crucial to find the right kind of tracer, one which would be suited to this study. In fact, the choice of the tracer is the most important key issue because it determines all of the further work in this study. After many experiments, the inorganic fluorescent powder is verified to be the best choice. Initially, a kind of nontoxic organic fluorescence reagent, Fluorescein, was tested in this study. This organic fluorescence reagent is inadequate because its fluorescence disappears after the completion of the curing process, although it has stronger fluorescence before the curing process. This is due to the absence of water after the curing process. The reasons for choosing the inorganic fluorescent powder are due to the following properties:

1. Easy to determine --- the "fluorescence dots" are visible under long-wavelength ultraviolet light on the surfaces of specimens. This made the determination of the dispersion of solidifying reagent much easier.
2. Economic --- the amount of fluorescent powder used as a tracer in a solidification system to perform the determination of homogeneity is minute. This may increase the feasibility of this method in the application to remediated sites in the future after the laboratory data has been fully established.
3. Nontoxic --- the fluorescent powder used in this study was nontoxic. This may prevent operators from being poisoned during handling and also prevent remediated sites from secondary pollution. This safety feature is seldom observed with other widely used tracers, such as radioactive chemicals, dyes etc.
4. Inert --- the fluorescent powder was impervious to its physical environmental

conditions including temperature, pressure, and other constituents in a solidification system. Furthermore, this fluorescent powder was very stable in a solidification system due to its chemical inertness.

5. Persistent --- the illuminescence of fluorescent powder is permanent under UV light. This allows a more flexible time schedule to inspect the final products or treated sites after solidification processes have been completed.

3.2.2 Measurement of Tracer

The dispersion of solidifying reagent is known by measuring the dispersion of fluorescent tracer. Thus, the homogeneity of a solidification final product can be evaluated by statistically calculating the dispersion of the fluorescent powder. The solidification system products are regarded as homogeneous if the results show uniform dispersion of the tracer [2].

The key point in evaluating the homogeneity is how to measure the fluorescent reagent in the hazardous waste solidification system accurately, quickly and at low cost. A video imaging system is employed in this study. The fluorescent powder emits faint fluorescence while excited by ultraviolet light and it does not continue a measurable time after the end of excitation process. In order to excite fluorescence, two 6-watt ultraviolet lamps are used to provide uniform ultraviolet light on the surfaces of specimens as other light sources are completely eliminated. The tracer on the surfaces of specimens shows up as "fluorescence dots" under these conditions. The images of specimens are taken by a video camera and shown on a high resolution monitor which is connected to a personal computer. The pictures shown on the monitor are image-captured and converted to a tremendous amount of data by the computer. The principle hardware used in this study will be discussed in the upcoming sections and the next chapter.

3.3 Imaging System

The image shown on a high-resolution monitor is composed of 204,800 (512 × 400) pixels. The brightness of each pixel on the monitor is composed of three colors : red, green, and blue. The brightness of each color ranges from 0 to 31. This information is stored in the computer when the image on the monitor is converted to digital data by the imaging software installed in the computer. A data file which occupies about 409,600 bytes (204800 pixels × 2 bytes/pixel) is created to store all the data obtained from the monitor. Thus, this data file is able to be analyzed by other programs.

3.4 Data Analysis

An image data file is just a long series of data before it is organized. A program is needed to analyze these data with respect to the distribution of the tracer on the surface of each specimen. The image of the specimen surface is divided into many segments in order to evaluate the homogeneity of the specimen. B. M. Rzyski and A. A. Suarez [1] divided their specimen into ten segments with different shapes when they studied the homogeneity of radioactive waste forms. They evaluated the homogeneity of solidified radioactive waste by using the standard deviation which is expressed as follows :

$$S.D. = \sqrt{\frac{\sum (X_i - \overline{X})^2}{n-1}}$$

where, S.D. : standard deviation

X_i : detected value of each segment

$\overline{X}$: average value

n : number of segments

Furthermore, the size of segments must be considered while evaluating homogeneities. Michaels and Puzinauskas [12] have shown experimentally that the mixing uniformity of a given mixture is inversely proportional to the square root of the volume of the samples taken from the mixture to determine the mixing homogeneity.

CHAPTER 4
EXPERIMENTAL APPARATUS AND PROCEDURES

4.1 Experimental Apparatus

The apparatus used in this study are described in the following subsections:

4.1.1 Preparation of Specimens

(1) Rotating Mixer with a B Flat Agitator

Manufacturer	: Hobart Company
Model	: A200
Power	: 1/2 Horsepower

(2) Cardboard Cylinder Molds

Manufacturer	: Soiltest Company
Model	: CT-508
Size	: 4"(diam.) ×× 8" (102 × 203 mm)

(3) Standard Compaction Hammer

Manufacturer	: Soiltest Company
Model	: CN-415
Hammer	: 2" diam. (50.8 mm); 5.5 lbs. (2.49 Kg)
Drop	: 12" (305 mm)
Weight	: Net 9 lbs. (4.1 Kg)

(4) Electronic Precision Balance

Manufacturer	: Soiltest Company
Model	: E-4000
Capacity	: 4000 g
Readability	: 0.1 g
Stabilization Time	: 2.5 seconds

(5) Electronic Precision Balance

Manufacturer	: Sartorius Company
Model	: H-110
Capacity	: 120 g
Readability	: 0.0001 g
Stabilization Time	: 3.5 seconds

4.1.2 Analytical Equipment

(1) Two UVP Longwave Hand Lamps

Manufacturer	: Fisher Scientific Company
Model	:11-984-2
Wave length	: 365 nm
Power	: 6 watts
Intensity	: 750 μ w/cm^2 of 365 nm at 6" (15cm)

(2) Video Camera

Manufacturer	: JVC
Model	: GRA-30

(3) High resolution Monitor

Manufacturer	: SONY
Resolution	: 512 × 400

(4) Personal Computer

Manufacturer	: IBM
CPU	: 80386

(5) Image Capture Board

Manufacturer	: Microsoft
Name	: Targa

4.2 Experimental Procedures

All of the detailed experimental procedures in this study are described in the following two subsections including preparation of specimens, and analysis of specimens.

4.2.1 Preparation of Specimens

The composition of the specimens is shown in Table 1.

Table 1 The Composition of the Specimens

Ingredient	Weight
Ottawa sand	932 g
Kaolin	468 g
Type I Portland cement	300 g
Water	300 g

First, the specimens are prepared from 468g of kaolin and 932g of Ottawa sand (clay:sand=1:2) mixed in the Hobart rotating mixer for a minimum of 10 minutes to assure that this simulated contaminated soil was uniform. The reason for using kaolin and Ottawa sand is that both of these materials have very uniform properties such as particle size which makes their mixing properties very constant.

Meanwhile, 300 g of type I Portland cement is prepared by addition of 0.02g, 0.06g, or 0.12g (10ppm, 30ppm, or 60ppm of total sample by weight) of fluorescent powder as a tracer. The Portland cement and fluorescent powder are very well mixed before being combined with other ingredients. A 4-watt portable ultraviolet lamp is used to inspect this mixture for assuring that the dispersion of the fluorescent powder in the cement is completely uniform. The 300g of water is divided into two parts. First, 220g of water is poured into the mixture of clay and sand and further sufficient mixing is supplied to get a damp and uniform soil. The other 80g of water is added to the mixture of Portland cement and fluorescent powder and further sufficient mixing is also supplied for this mixture.

The water is added into two constituents separately in order to get equally "bad-mixing" specimens with adequate repeatability. The mixed soil is loosely placed onto the bottom of mixing bowl and the Portland cement is then uniformly spread on the soil. After these steps are completed, the rotating mixer is turned on. The mixing times used are 5, 10, 20, 30, and 60 seconds. Five samples with different mixing degrees are duplicated for each fluorescent powder concentration.

After the mixing is completed, nine samples are randomly taken from the mixture for chemical analysis of the calcium content. Each sample is about 5 grams. The results of the instrumental analysis will be compared with the results of the imaging analysis. Half of the remaining mixture is transferred into a cardboard mold which is 4 inches in diameter and 8 inches in height [13]. The standard compaction hammer is then used to uniformly compact the specimen in each of 12 directions. The other half of the mixture is then added to the mold and the compactions repeated. Like mixing, compaction is still a form of energy that can increase the mixing degree of the specimen, thus, the time duration for compaction has to be controlled carefully in order to minimize its effect on the homogeneity of the specimens.

The specimens are cured at room conditions to get solidification. After 4 hours from the beginning of curing, each specimen is cut into 5 pieces with the same thickness. Every piece is placed on a clean board separately, marked for identification, and allowed to completely cure. These specimens are held for at least 24 hours in order to solidify before they are analyzed.

4.2.2 Analysis of Specimens

The imaging system employed in this study, in terms of hardware, includes a video camera, a high resolution monitor, a personal computer with an image capture board, and some computer programs used to obtain and calculate the data. This system's working flow chart is shown in Figure 1. First, a piece of specimen is put into a black box mounted with a video camera. Two 6-watt ultraviolet lamps installed in the box are then turned on to create uniform and sufficient ultraviolet light in the black box while all other light sources are eliminated to prevent the fluorescence on the surface of specimen from being washed out. The image of the surface of the specimen is taken with a video camera and shown on a 512 by 400 high resolution monitor which is connected to the video camera. At this stage, the dispersion of the fluorescence dots on the surface of specimen can be seen very clearly on the monitor.

The image on the monitor is then converted to 409,600 bytes (204800 pixels × 2 bytes/pixel) of data by the image capture board and associated software and then stored in a data file by the computer. Each pixel on the monitor shows an intensity ranging, theoretically, from 0 to 93. All of the pixels show intensities much lower than 93 in practice. The analysis of these data files is done by means of a computer program written in the FORTRAN programming language. This program is a part of this study and is included in Appendix A.

In this study, each image is "divided" by computer in two ways: (1) into equal-area pie shapes and (2) into equal-area annular areas. These divisions are shown in Figure 2. Both ways are used to divide the circular surface of specimen into 36 equal-area segments. Each segment contains approximately contained 2500 pixels on the monitor.

For each method of division, two different ways of calculating the homogeneity

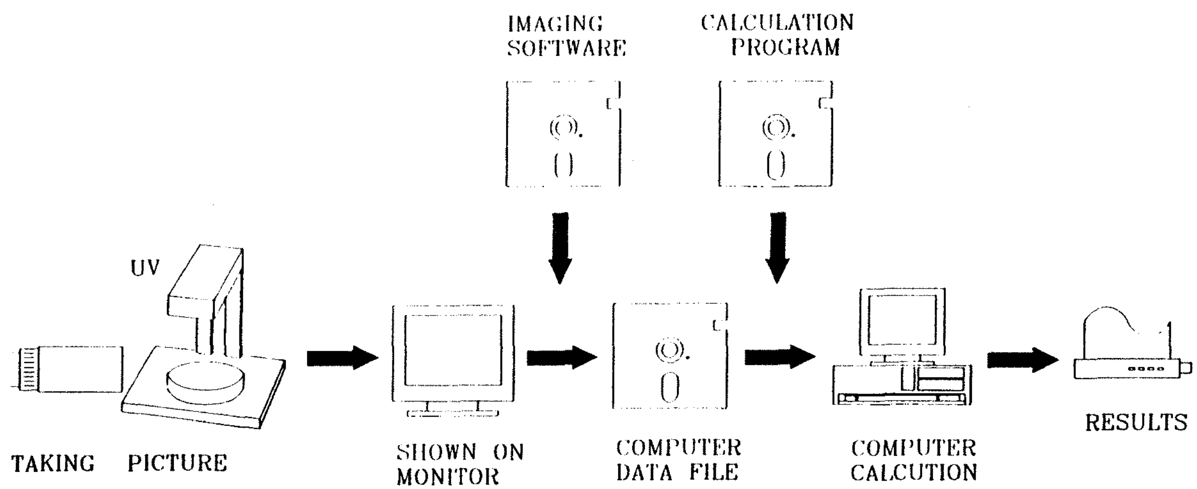
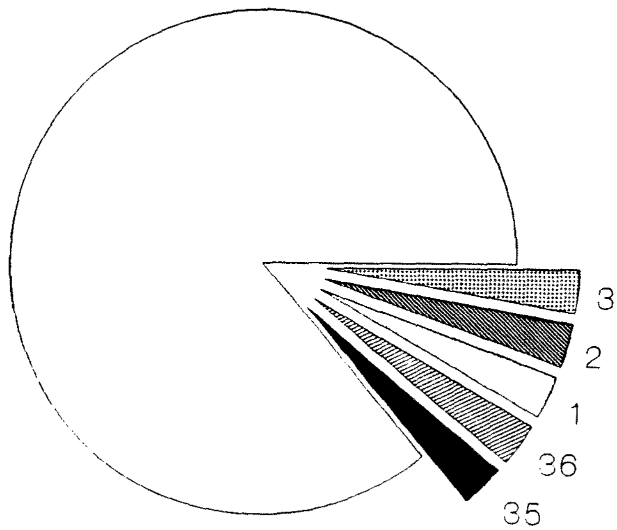
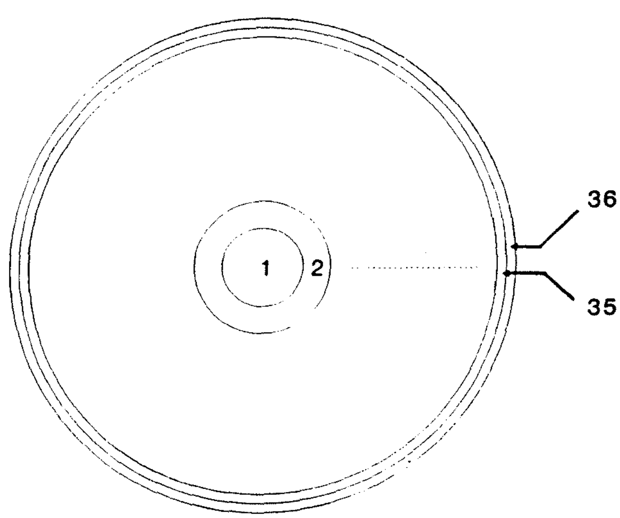


Figure 1 HEVIS working flow chart



(a)



(b)

Figure 2 Specimen division for data analysis: (a) divided into 36 equal-area pie shapes. (b) divided into 36 equal -area annular areas.

are considered. The first procedure is to count the number of pixels which had intensities higher than or equal to the illuminescence intensity criterion in each segment. The second method is to add the intensities of the pixels whose intensities are higher than or equal to the illuminescence intensity criterion. The standard deviation is calculated based on the total number or intensity of a segment in a specimen. These standard deviations represent the homogeneities of the solidification products, which are further compared by plotting various figures.

In order to consider the size of segments while evaluating homogeneities, standard deviations are obtained for 36-segment, 18-segment, 12-segment, 9-segment, 6-segment, and 4-segment divisions. These results are also compared to evaluate the homogeneity of solidification product and to find the best analysis conditions.

To analyze the dispersion of fluorescent powder, the coordinates of the specimen on the screen must be known before the imaging data file is read and analyzed. The FORTRAN program is then used to statistically analyze the data file. An illuminescence intensity criterion is also input to the program to delete the pixels whose intensities are lower than this criterion. These pixels with lower intensities are regarded as background on the monitor and, conversely, the fluorescent dots are recognized as those pixels with intensities higher than the illuminescence intensity criterion.

In this computer program, the number of pixels is first reduced to one fourth by combining every four adjacent pixels in order to save computing time. Then, each combined pixel is tested to ensure that it is within the area of specimen. Only the pixels located within the area of the specimen are compared with the illuminescence intensity criterion. Any pixel with an intensity higher than or equal to the illuminescence intensity criterion is further identified as to which segment it is located in. All the pixels located in the same segment are summarized. There are four different standard deviations calculated in this program based on the following 4 different conditions :

(1) the total fluorescent pixel number in a pie-shape segment,

(2) the total intensity of the fluorescent pixels in a pie-shape segment,

(3) the total fluorescent pixel number in a annular segment, and

(4) the total intensity of the fluorescent pixels in a annular segment.

All these results are shown and discussed in chapter 5.

CHAPTER 5
RESULTS AND DISCUSSION

In order to assess the feasibility of Homogeneity Evaluation by Video Imaging System (HEVIS), the results of HEVIS studies are compared with the results of instrumental analysis. Figure 3 shows the instrumental analysis results by Atomic Adsorption (AA) Spectroscopy [14]. That study calculates the standard deviation in calcium content among the nine samples taken from each specimen. The resulting standard deviations are then plotted versus mixing time in the figure. This standard deviation curve clearly indicates the relationship between the mixing time and the homogeneity of solidification products.

In order to achieve the optimum image analysis conditions, the division of the specimen must be fixed at a certain level to find the optimum Illuminescence Intensity Criterion (I.I.C.). First of all, the number of segments is fixed at nine to study the variation of homogeneity (standard deviation) with various illuminescence intensity criteria. Figures 4 to 13 show these analysis results.

The I.I.C., in Figure 4, is equal to 10. Four different standard deviation curves by four different statistical calculations are shown in this figure. When these curves are compared with Figure 3, they do not match the curve from the instrumental analysis because the fluorescent dots on the surface of specimens are not being accurately recognized by the imaging system. The standard deviation for the total intensity in pie-shape segments at the 5-second mixing time is too low because too many pixels have intensities higher than the I.I.C.

For an I.I.C. of 16, the analysis result is shown in Figure 5. These curves still do not match the instrumental analysis curve of Figure 3. The standard deviation curves are still not correct as the I.I.C. is raised to 22. These results are shown in Figure 6.

The standard deviation curves became better when the I.I.C. is 24. The analysis results are shown in Figure 7. If the I.I.C. is further raised to 26, 28, 30, 34, and 40, the analysis results are shown in Figure 8 to 12, respectively. The optimum I.I.C. value is found to be 28 as shown in Figure 9. In this figure, the standard deviation curve for the number of pixels in pie-shape segments, more clearly shown in Figure 13, shows the best match with the instrumental analysis curve based on the magnitude of standard deviations of 5 specimens. This indicated that the fluorescent dots could be clearly recognized by HEVIS when the I.I.C. is equal to 28. The analysis results of the division to annular areas do not show the same effect. This is felt to be due to the shape of rings. A "clump" of poorly mixed material is very unlikely to be completely contained within a single ring. Thus, the rings tend to indicate greater homogeneity than actually exists.

After the optimum value of the I.I.C. is found, the number of segments has to be changed to find the optimum number of segment divisions by HEVIS. With the I.I.C. fixed at 28, the number of segments is changed from 9 to 36, 18, 12, 6, and 4. These analysis results are shown in Figure 14 to 18, respectively. By comparing Figure 9 (number of segment equals to 9) to these figures, we find the standard deviation curve for the number of pixels in pie-shape segments still shows the best match with the curve shown in Figure 3.

From Figures 4 to 18, the optimum analysis conditions for HEVIS are found to be at a value of 28 for the I.I.C. and a value of 9 for the number of segments based on pie-shape division and total-pixel-number calculation.

In this study, the size of divided segment is also studied. Figures 19 to 24 show the mixing time of 5, 10, 20, 30, 60 and 180 seconds respectively when the number of segment ranges from 4 to 36. We find that the deviations become smaller as the mixing time becomes longer. When the specimen becomes more uniform, the homogeneity of the specimen will not have a large change no matter how the size of segment is chosen. This conclusion also agrees with the results shown in previous figures.

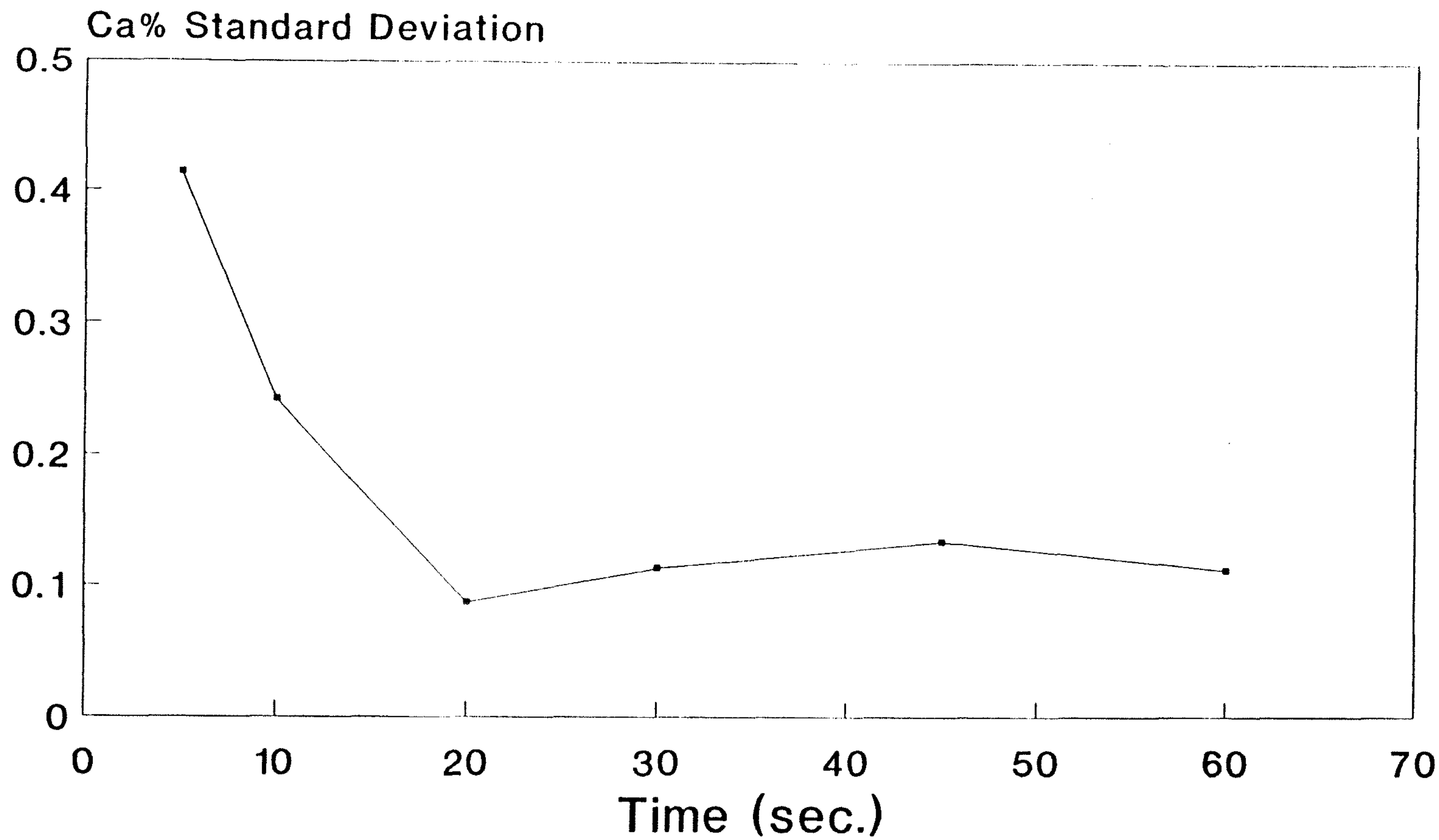


Figure 5-1 Homogeneity Evaluation
AA test method

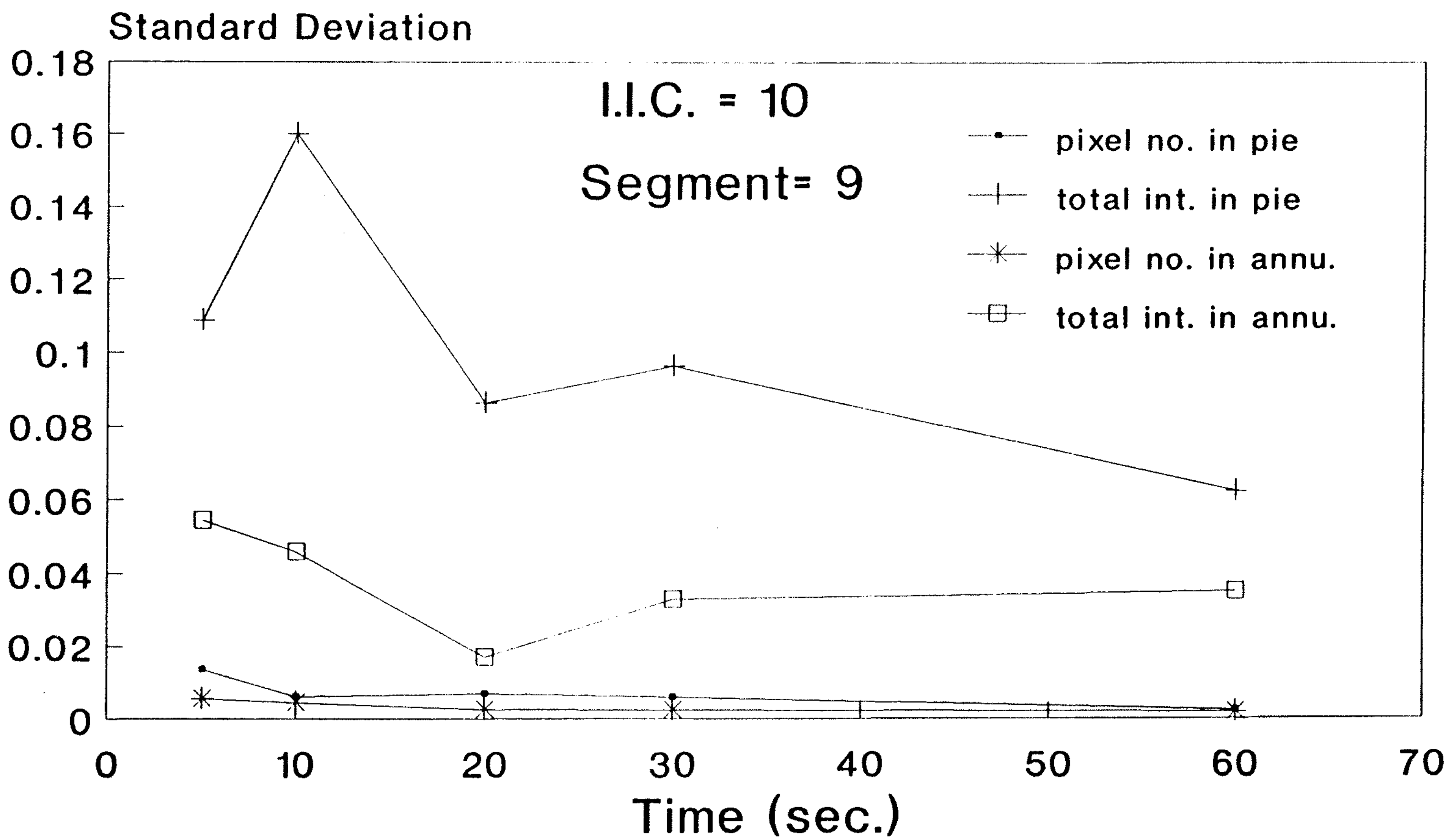


Figure 5-2 Homogeneity Evaluation
imaging test method

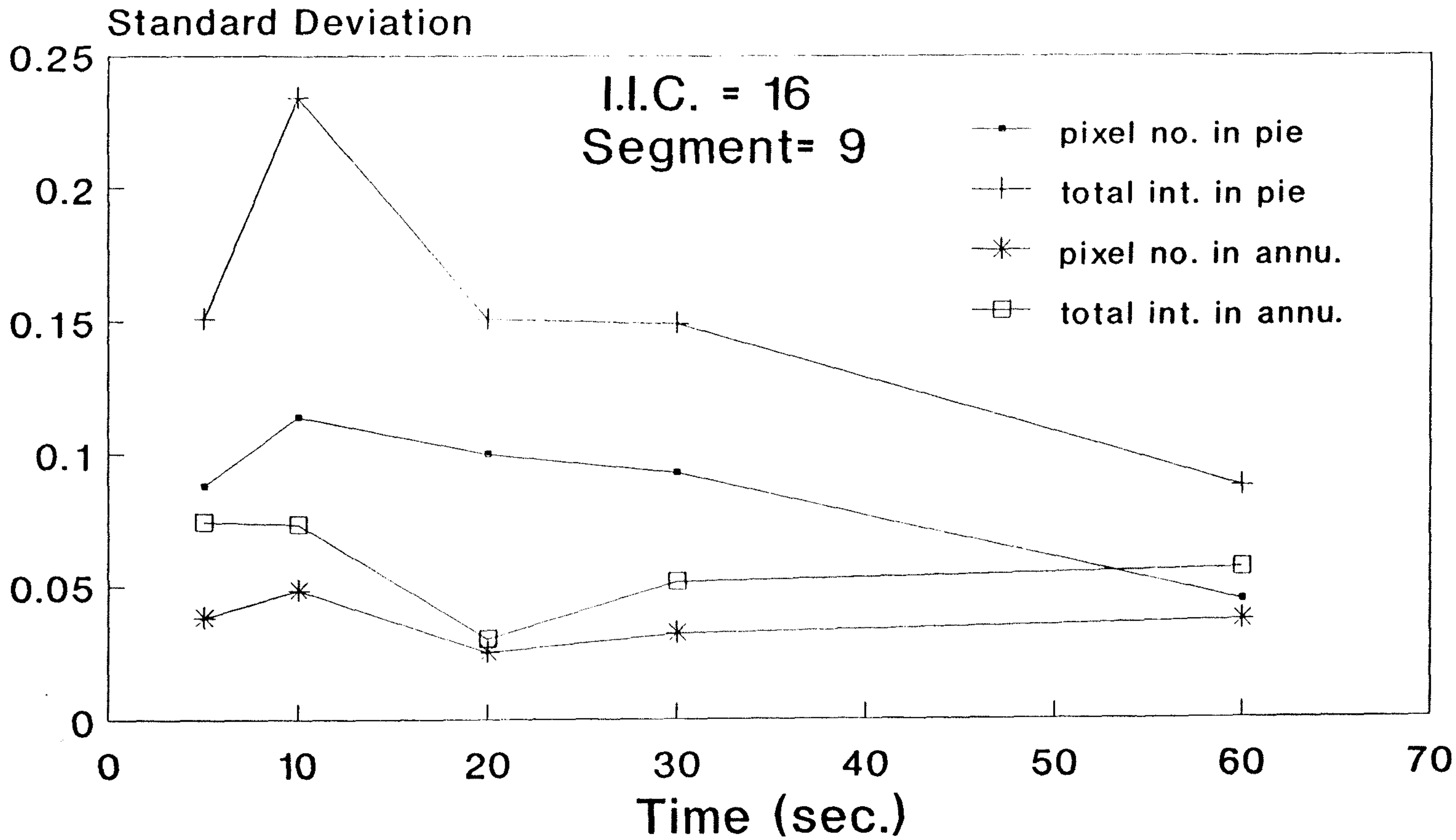


Figure 5-3 Homogeheity Evaluation
imaging test method

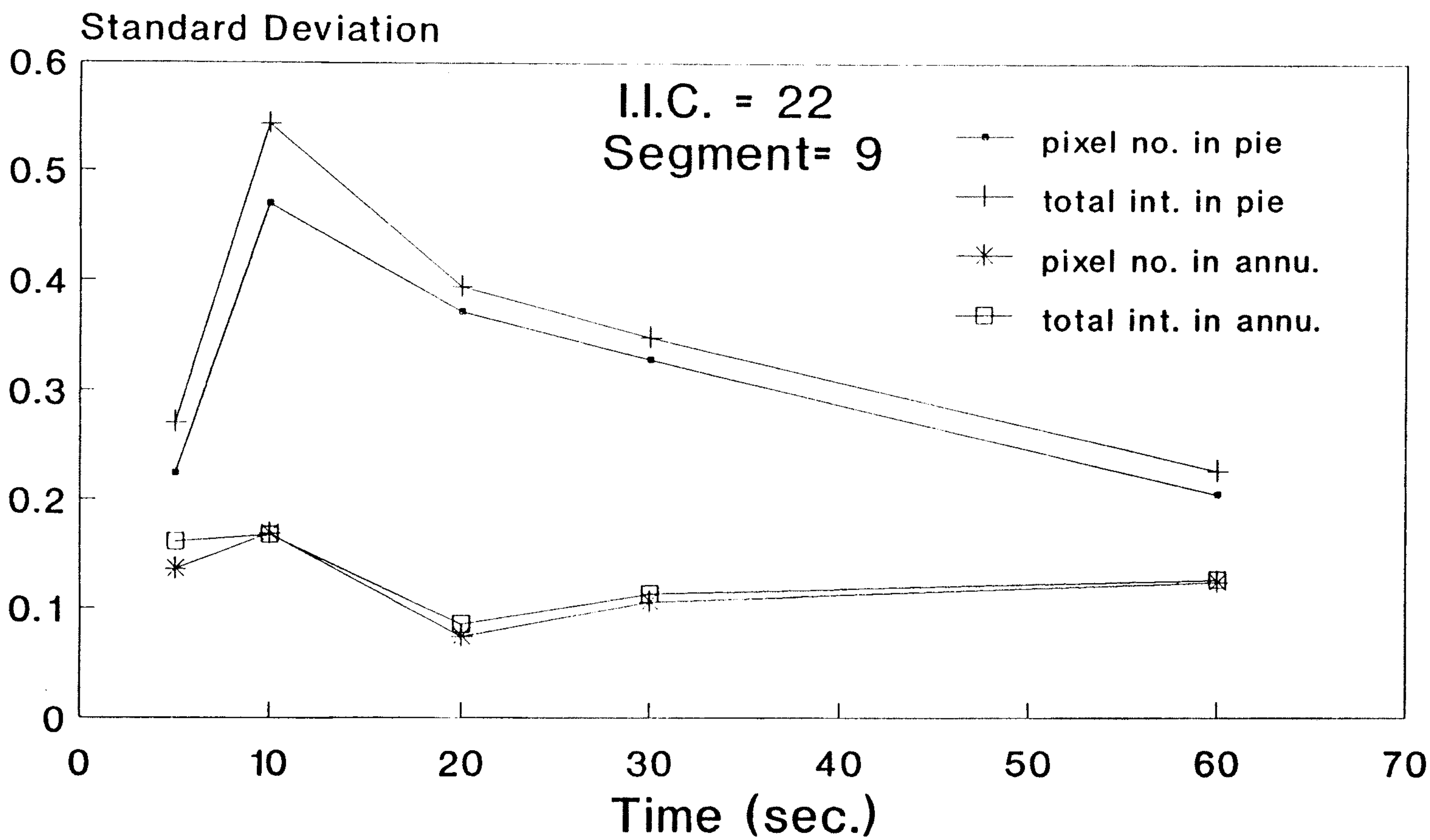


Figure 5-4 Homogeneity Evaluation
image test method

facing 33

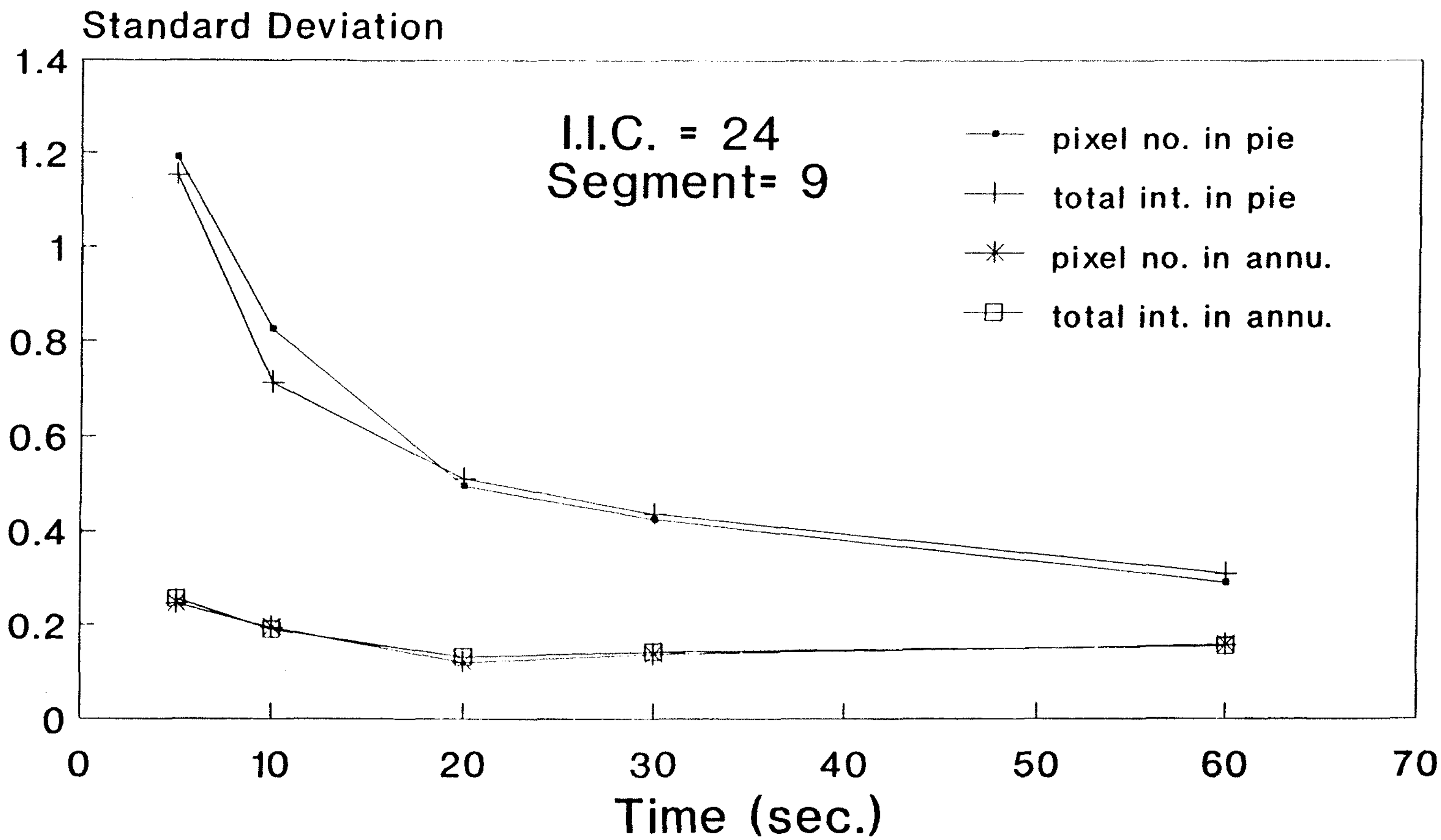


Figure 5-5 Homogeneity Evaluation imaging test method

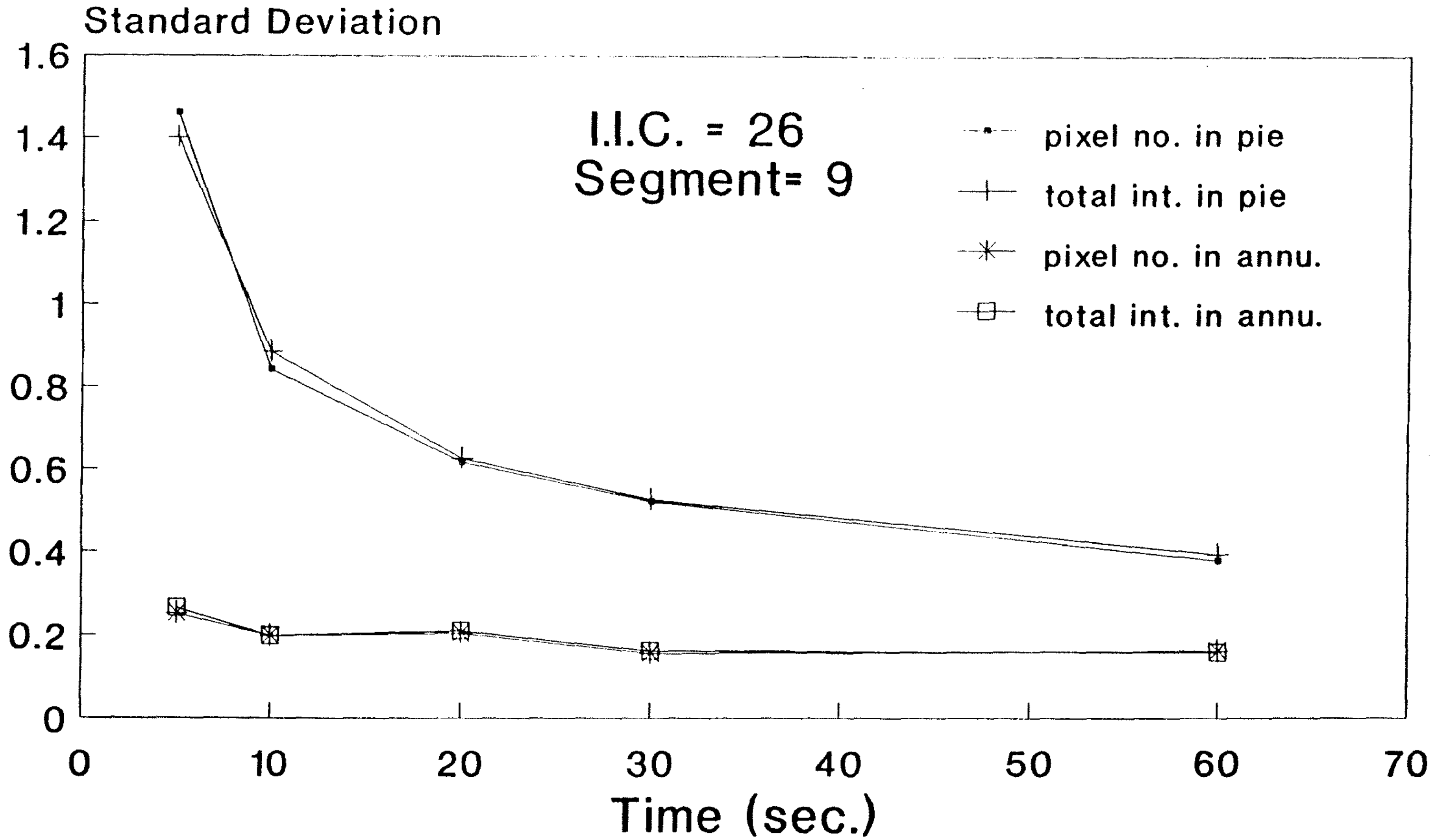


Figure 5-6 Homogeneity Evaluation
imaging test method

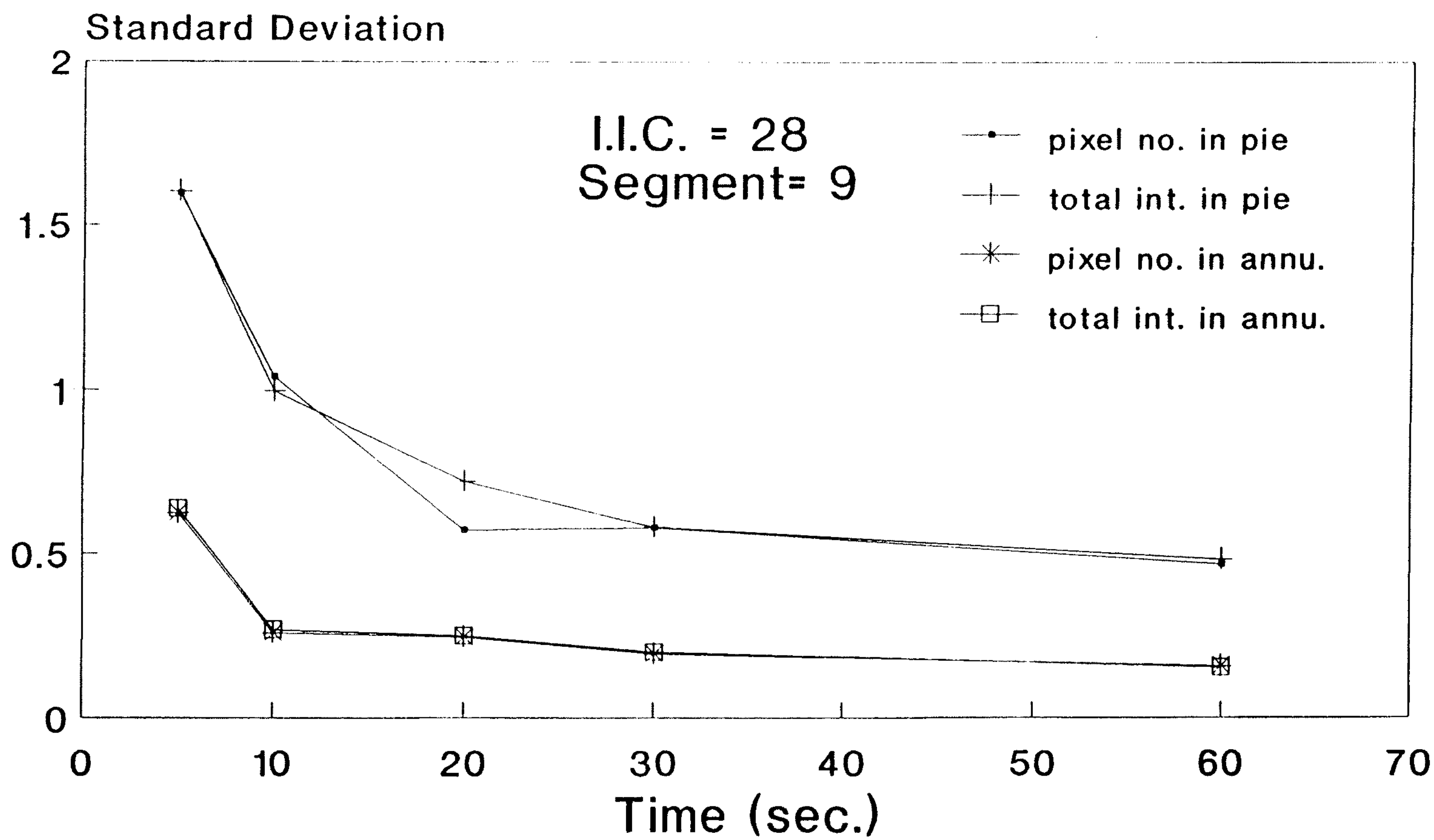


Figure 5-7 Homogeneity Evaluation
imaging test method

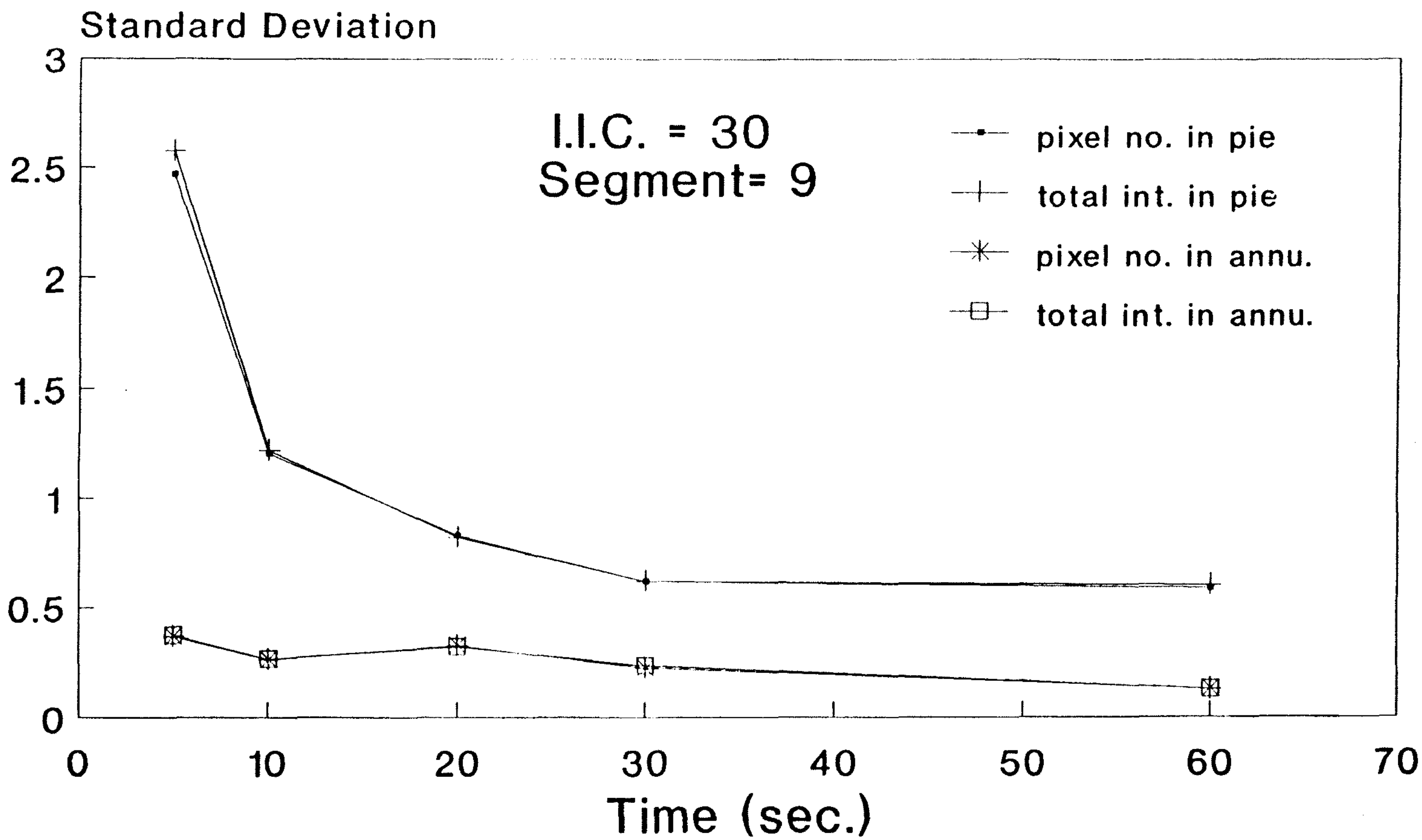


Figure 5-8 Homogeneity Evaluation imaging test method

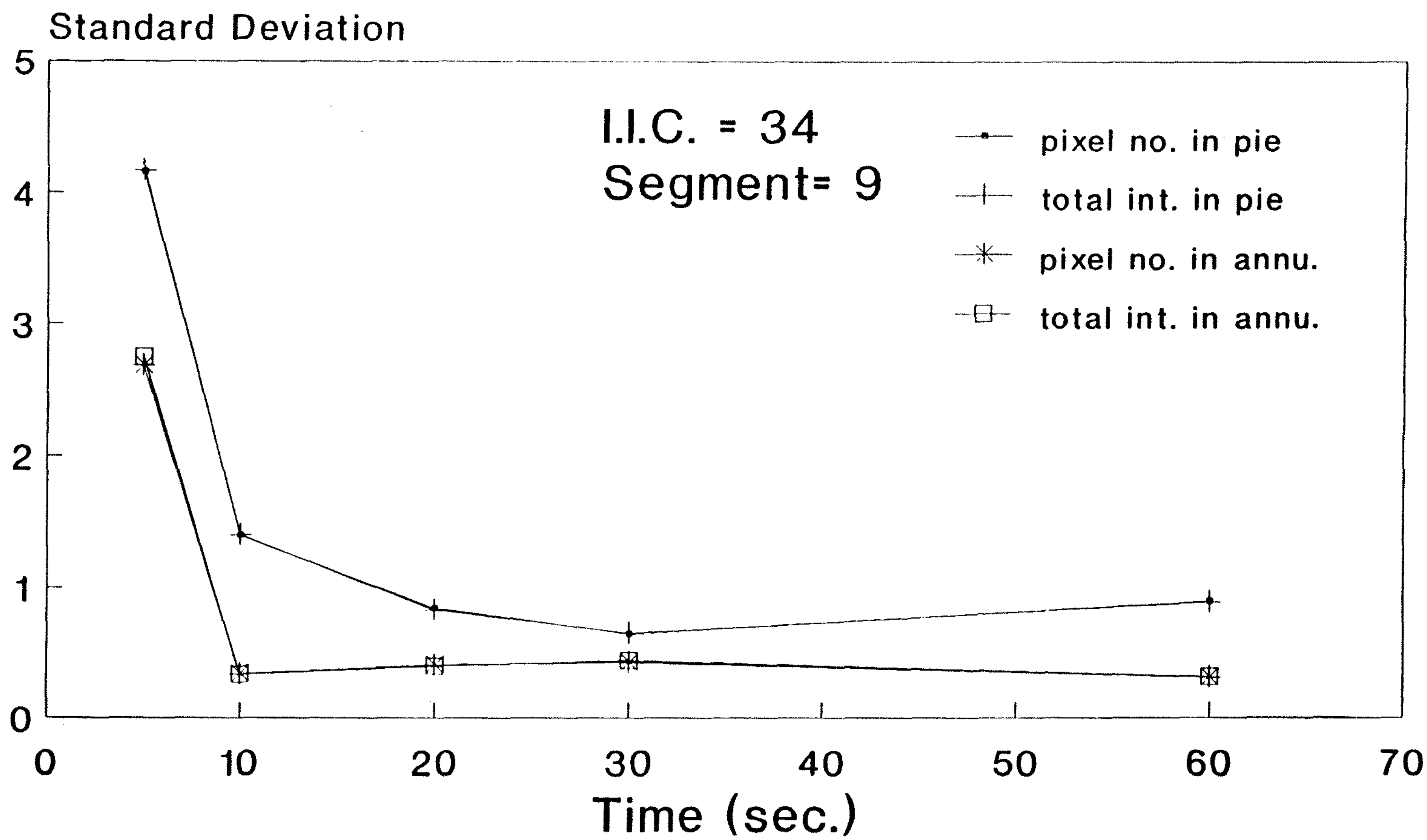


Figure 5-9 Homogeneity Evaluation
imaging test method

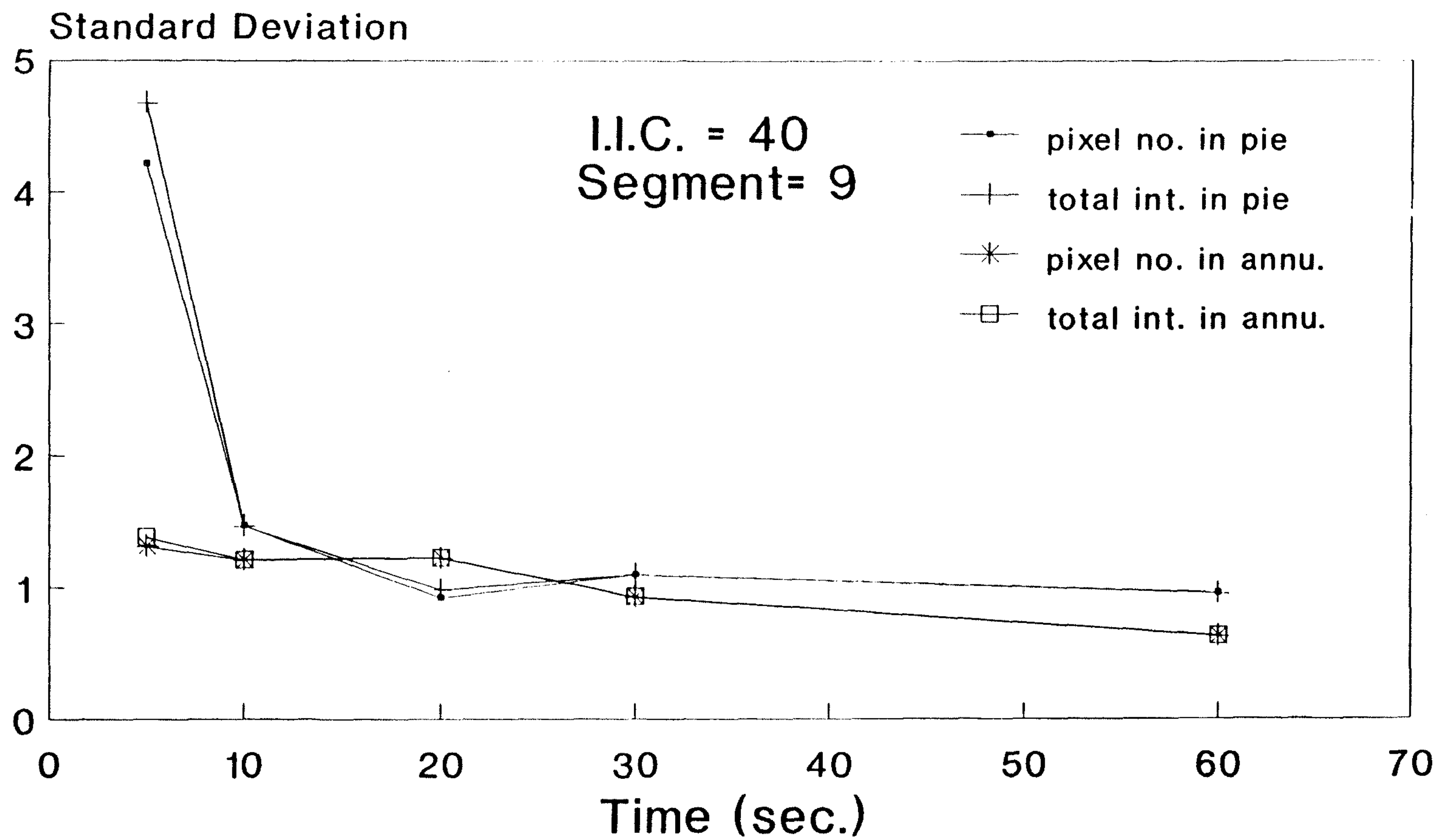


Figure 5-10 Homogeneity Evaluation
imaging test method

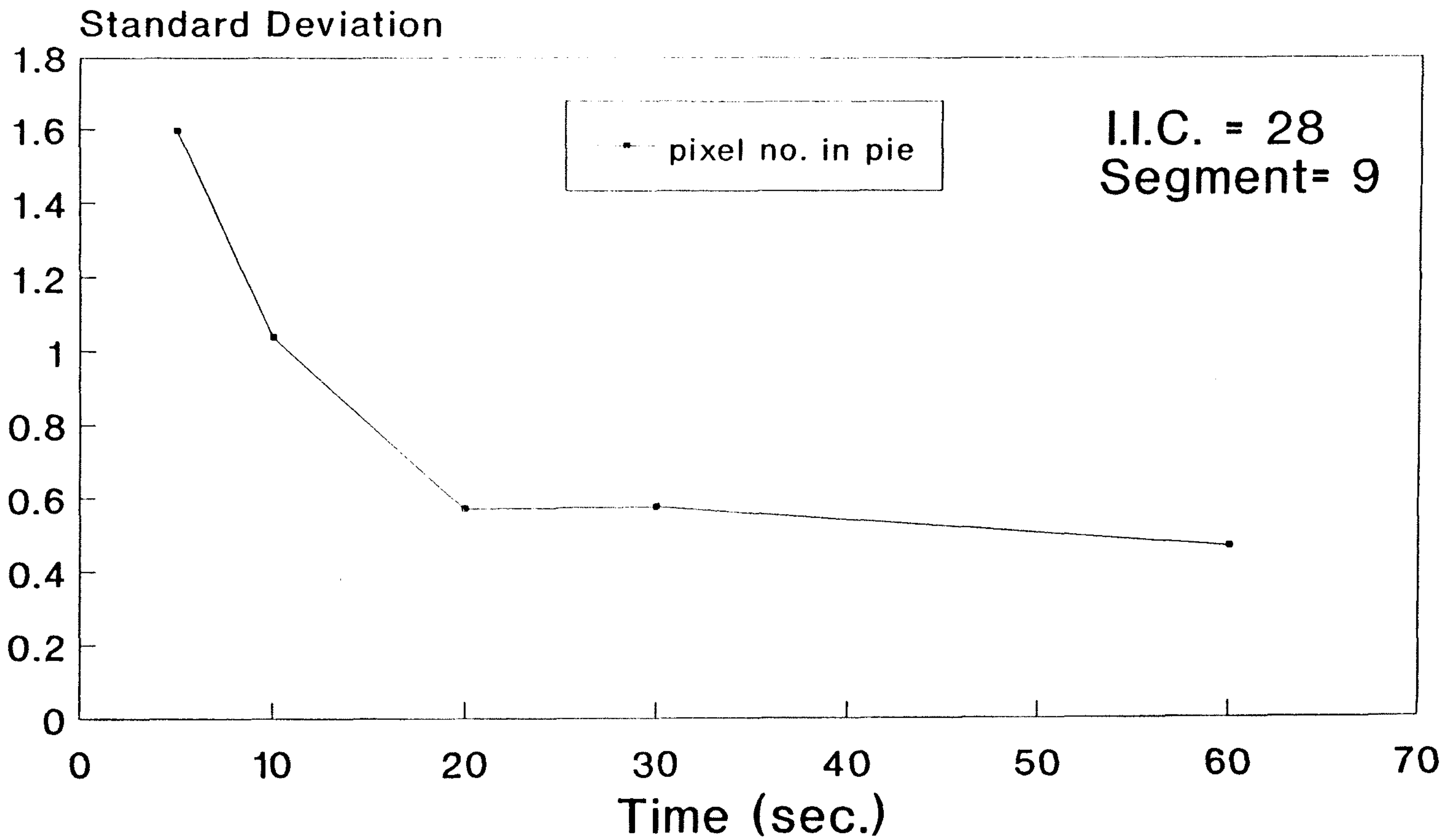


Figure 5-11 Homogeneity Evaluation
imaging optimum test

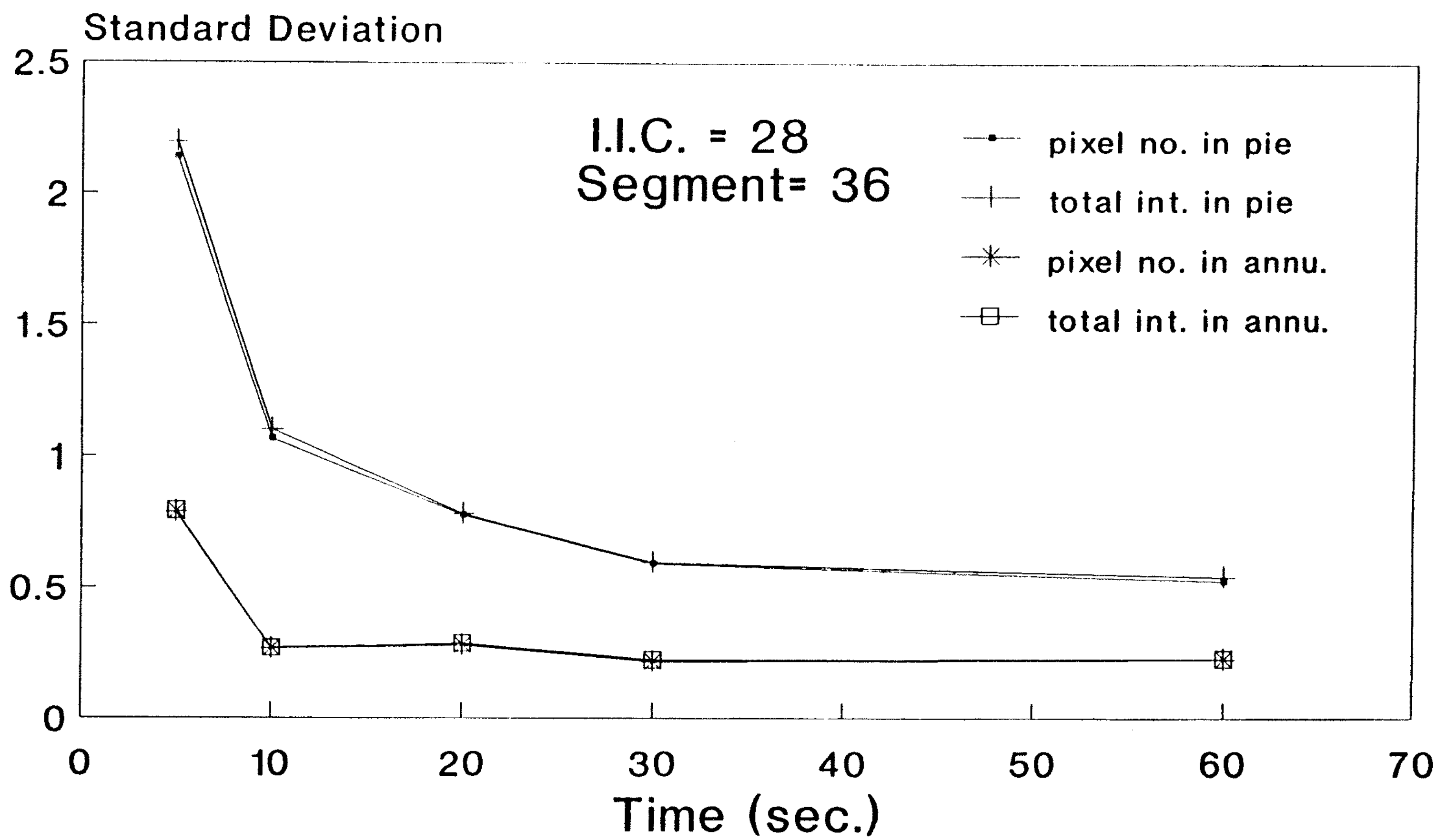


Figure 5-12 Homogeneity Evaluation
imaging test method

facing 41

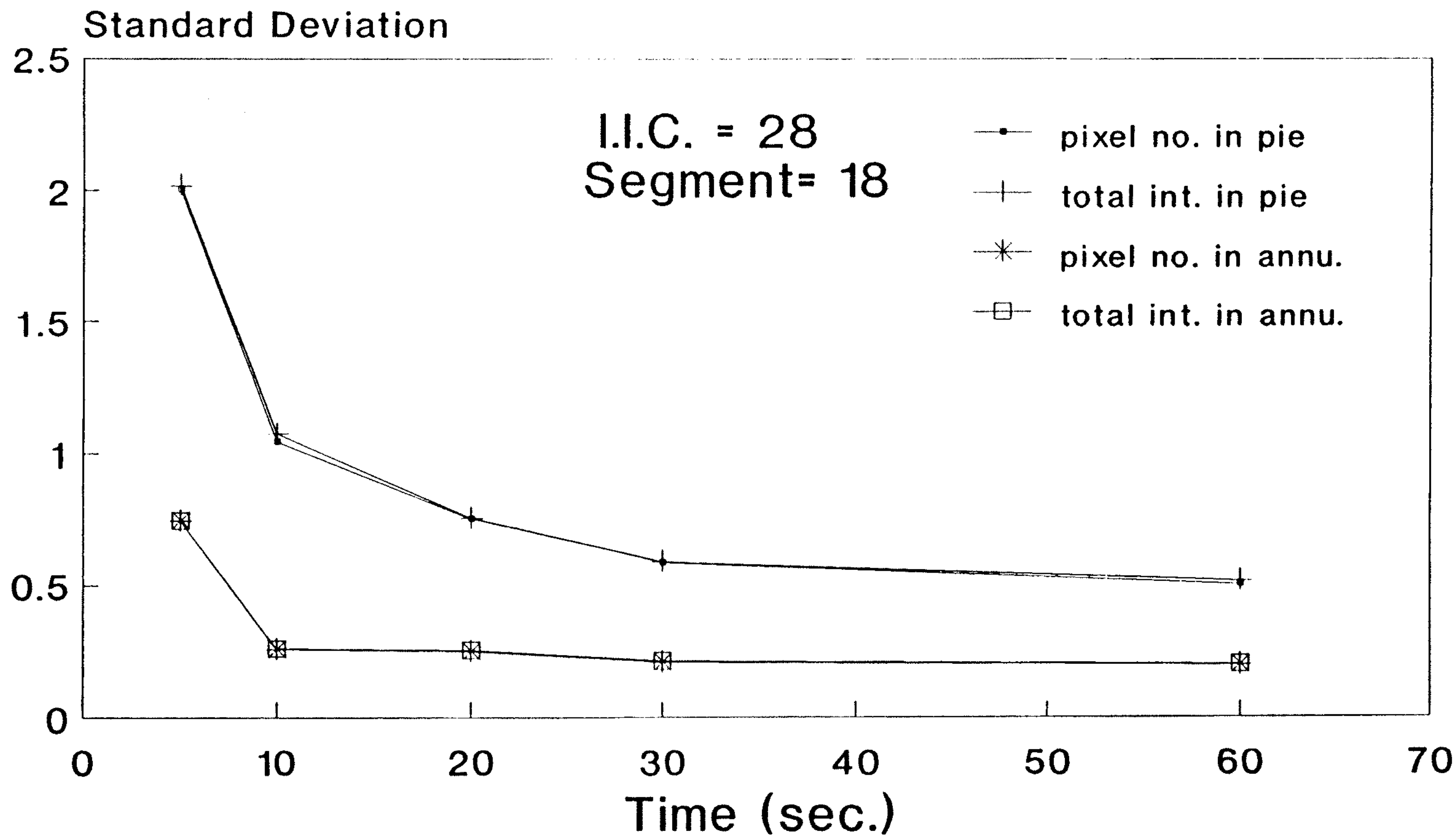


Figure 5-13 Homogeneity Evaluation
imaging test method

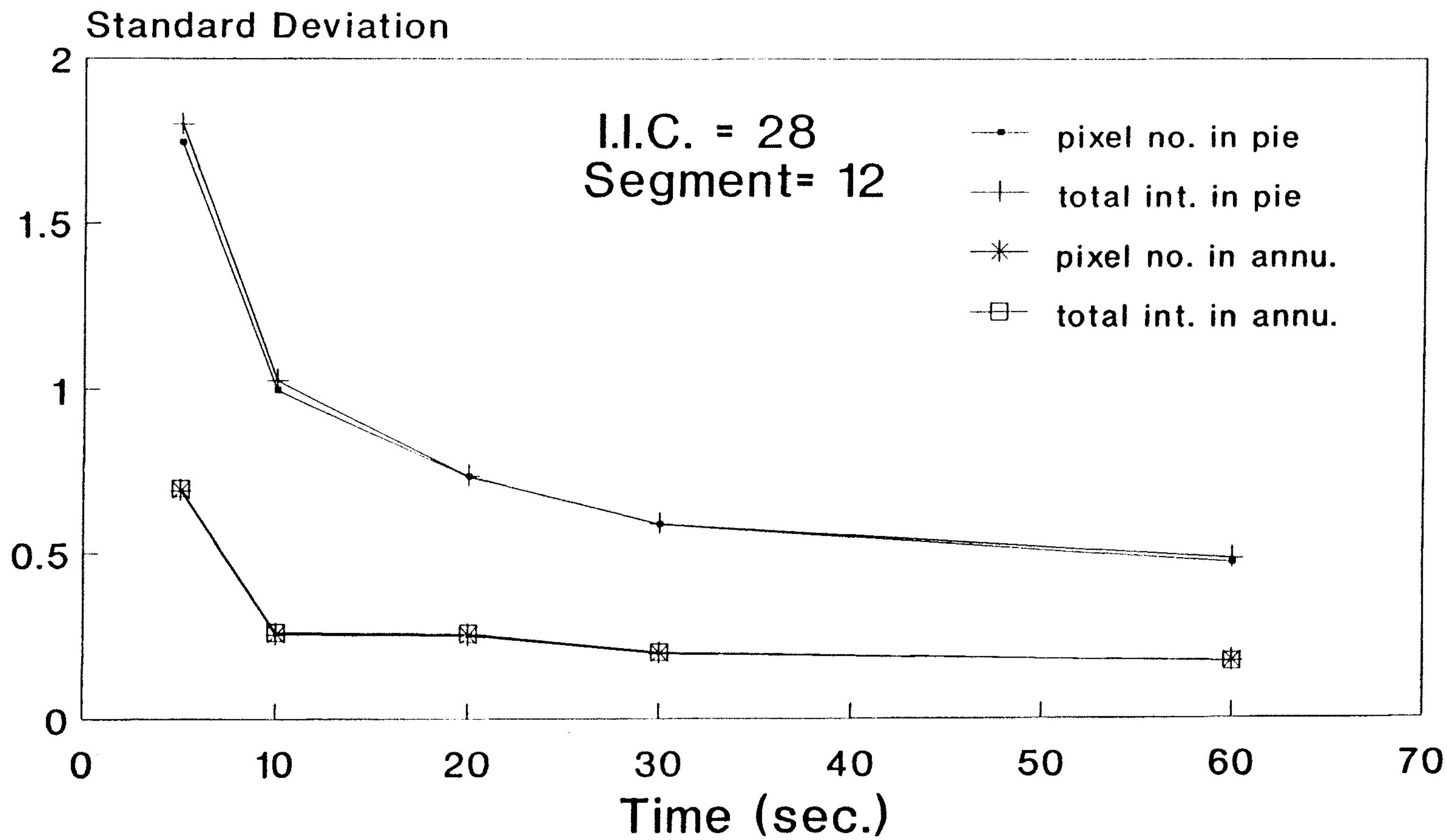


Figure 5-14 Homogeneity Evaluation
imaging test method

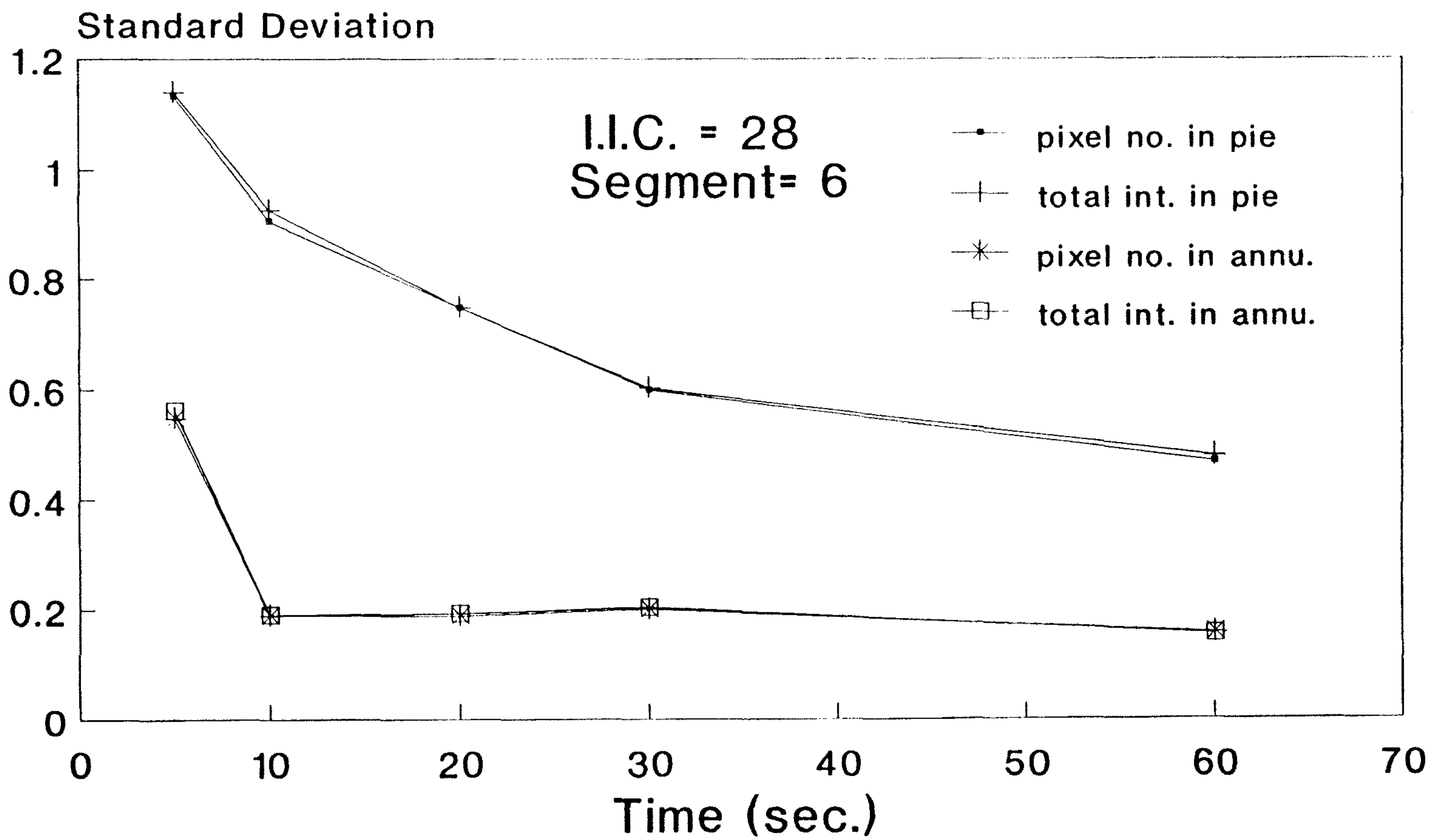


Figure 5-15 Homogeneity Evaluation
imaging test method

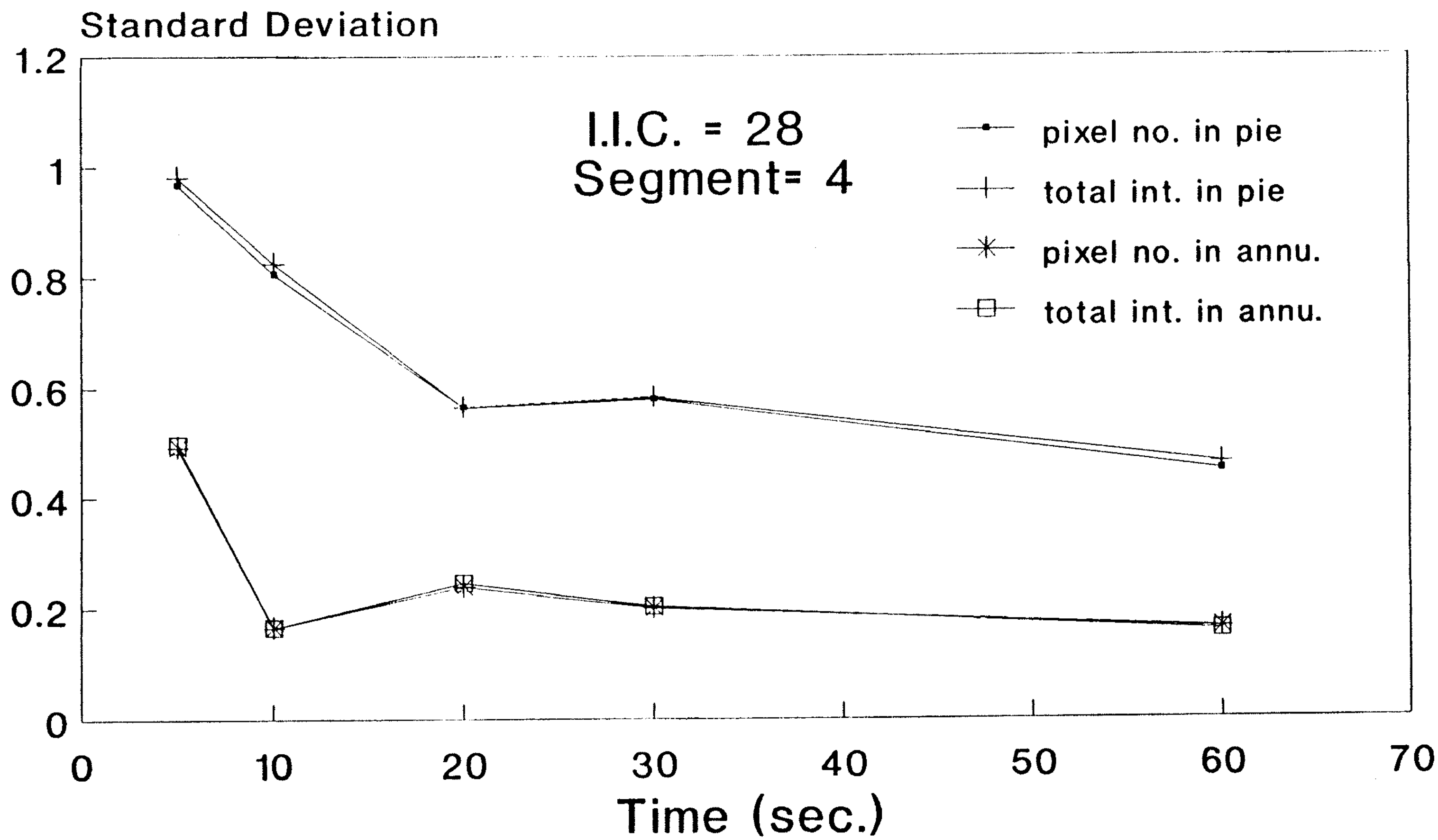


Figure 5-16 Homogeneity Evaluation
imaging test method

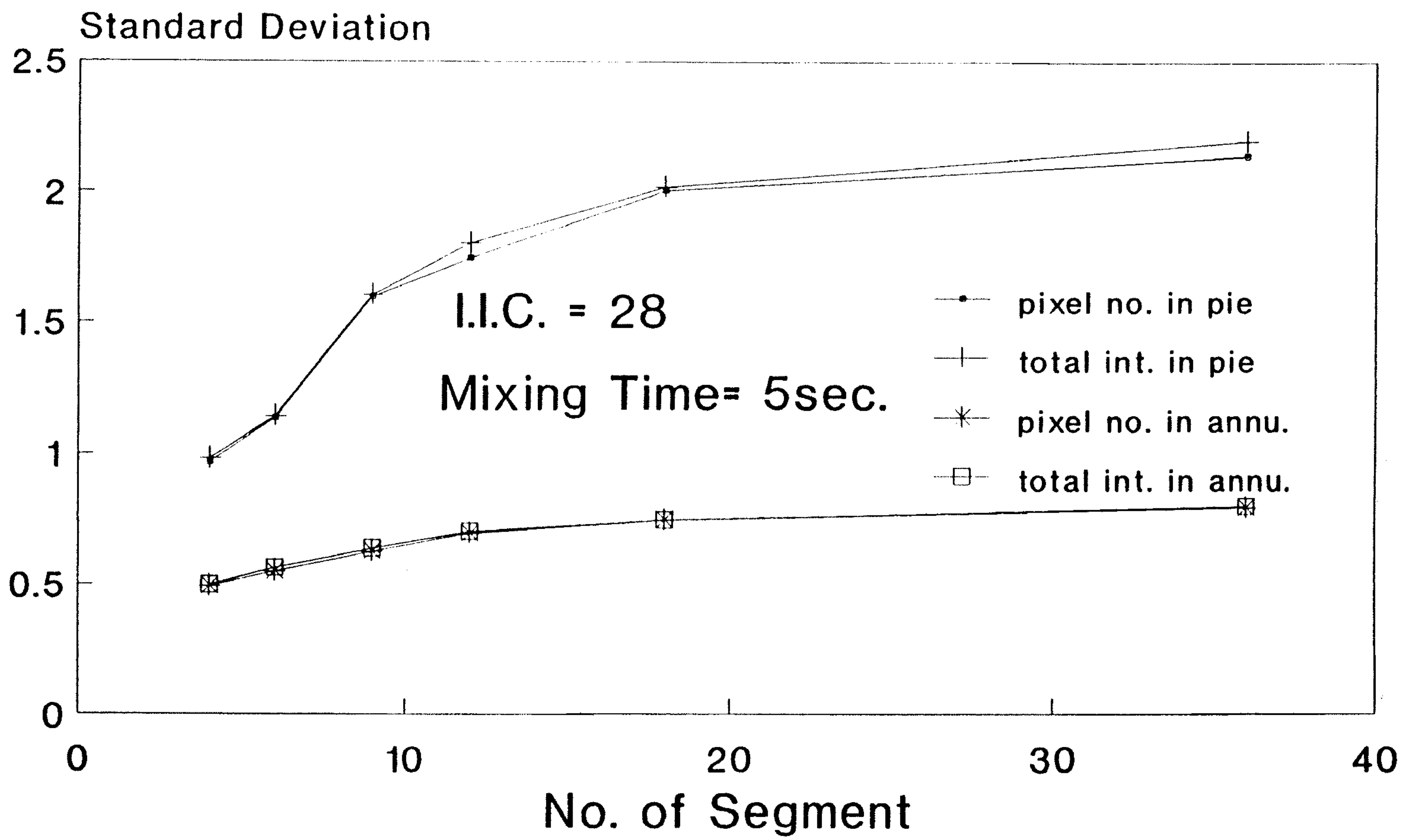


Figure 5-17 Homogeneity Evaluation
imaging test method

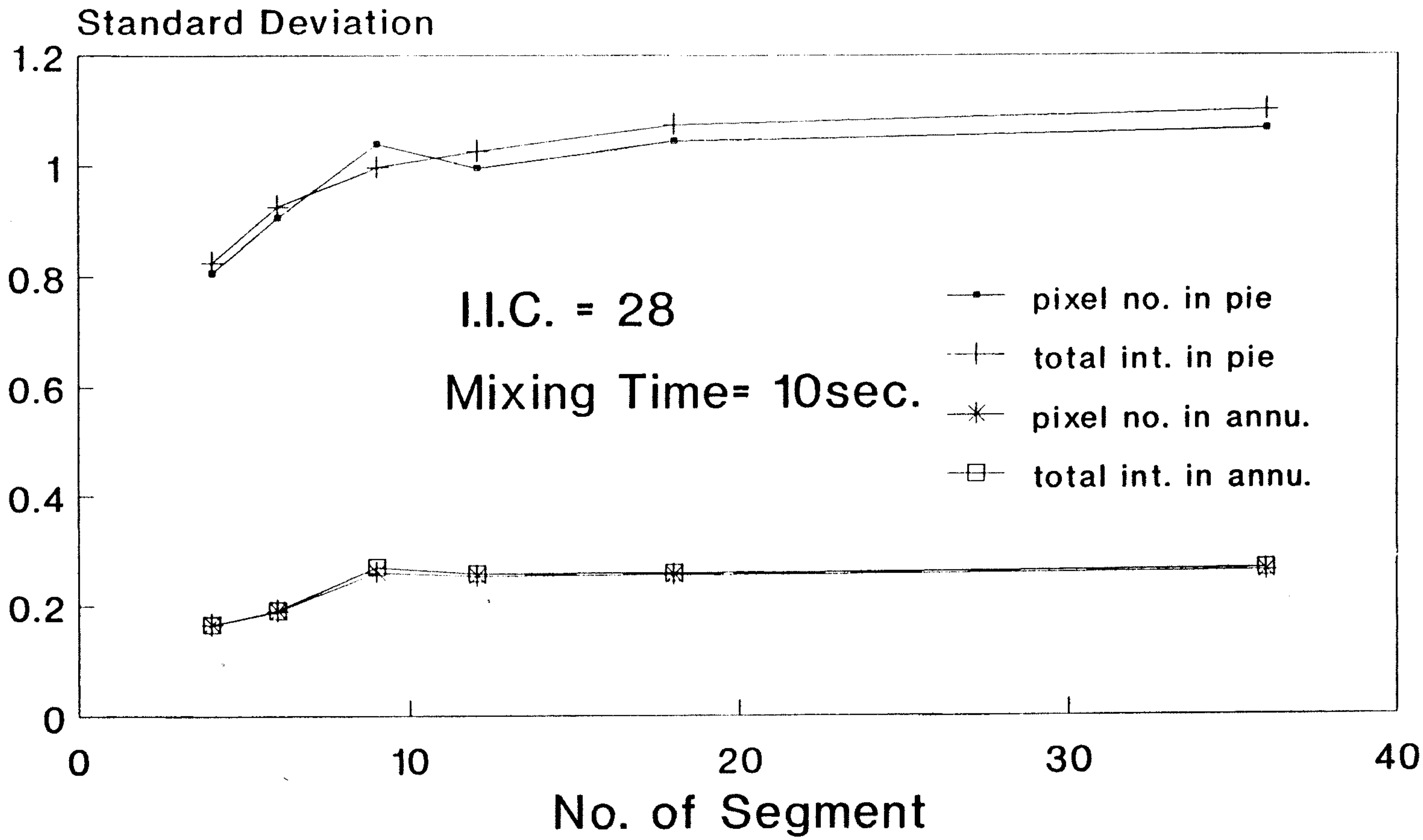


Figure 5-18 Homogeneity Evaluation
imaging test method

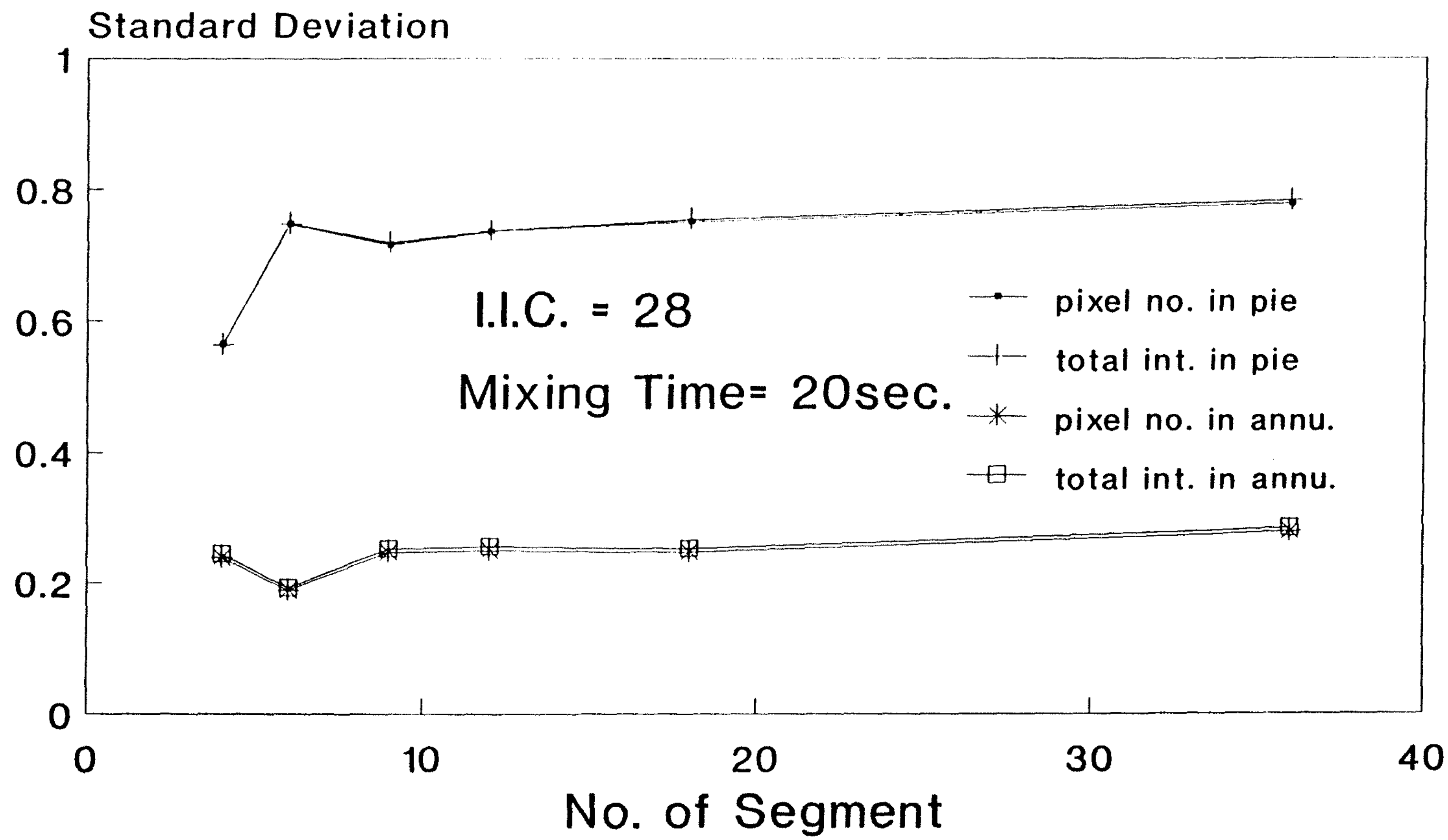


Figure 5-19 Homogeneity Evaluation
imaging test method

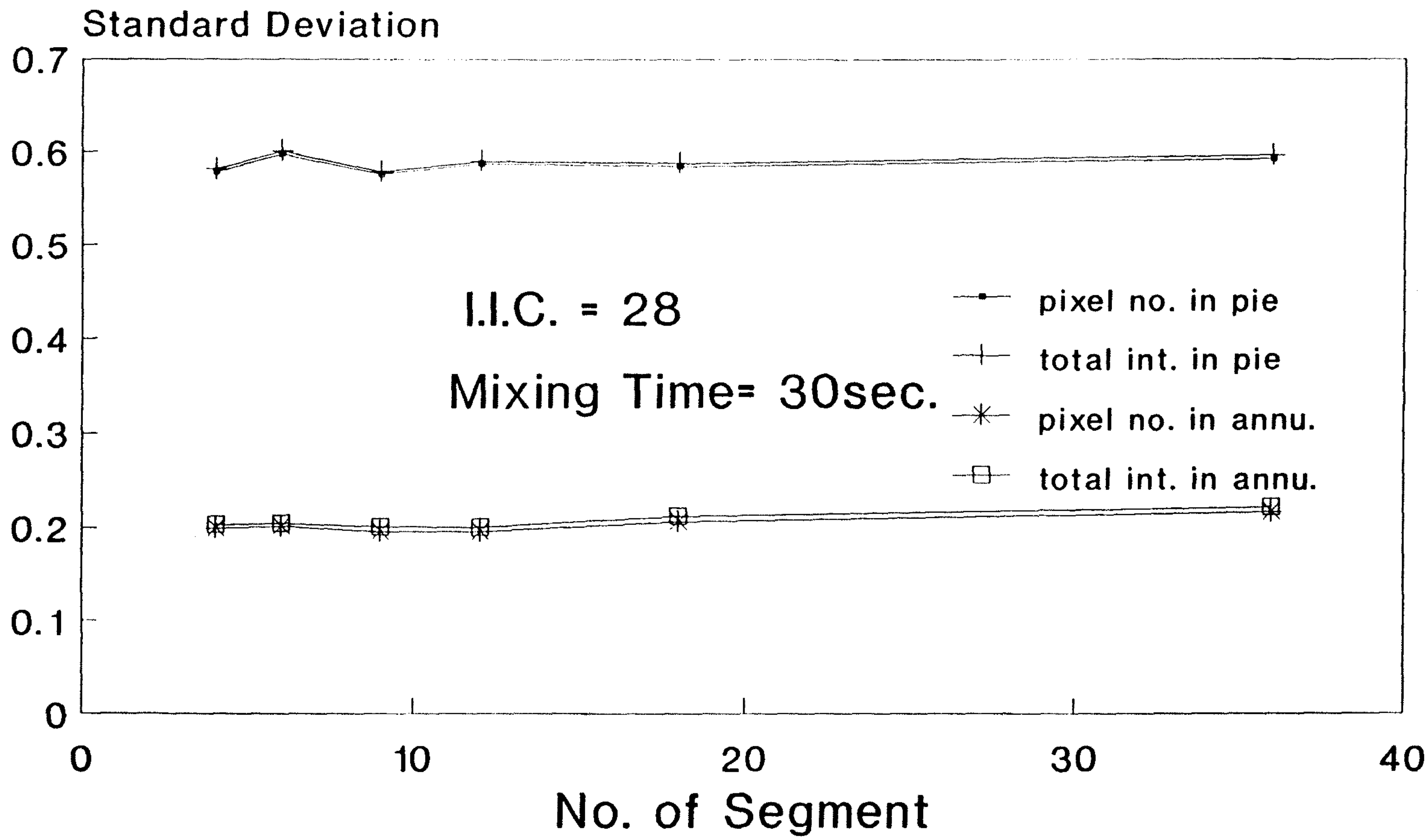


Figure 5-20 Homogeneity Evaluation
imaging test method

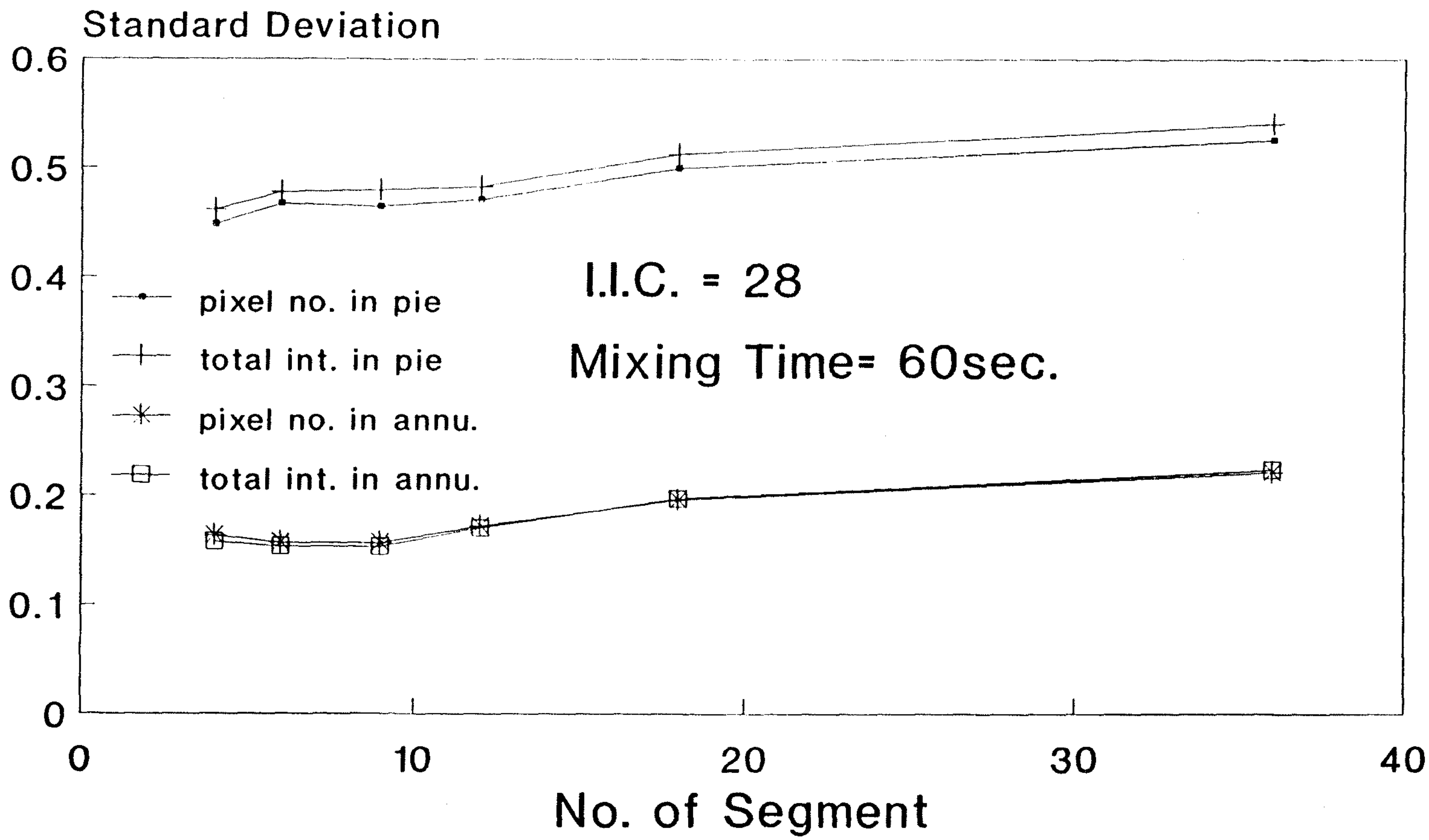


Figure 5-21 Homogeneity Evaluation
imaging test method

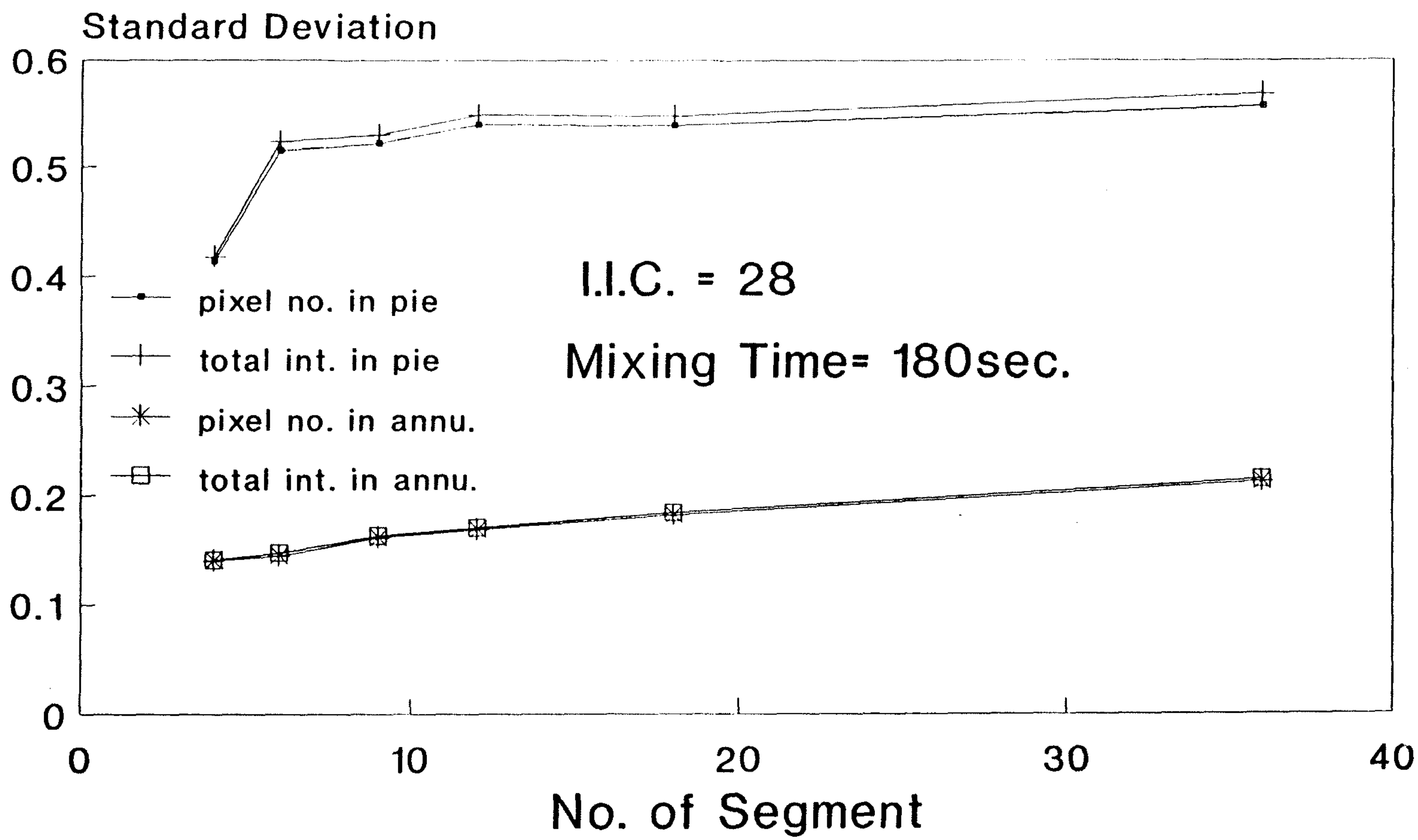


Figure 5-22 Homogeneity Evaluation
imaging test method

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

Some important conclusions and recommendations are derived from the results and are summarized as follows:

1. These experiments show the Homogeneity Evaluation by Video Imaging System (HEVIS) is both economically and technically feasible. The optimum analysis condition for HEVIS is found to match the homogeneity curve of the imaging analysis technique with the curve of the instrumental analysis technique. This means that HEVIS can be used instead of the instrumental analysis technique in the field evaluation of homogeneity as long as the optimum analysis conditions are found and setup. In this way, capital, time and manpower can be saved.
2. The optimum analysis conditions for each imaging system are constant as the operation conditions of system are determined. All the operation conditions do not need to be redefined after the HEVIS is completely setup.
3. The existing HEVIS can still be improved in order to make more precise homogeneity evaluations by using more suitable and effective equipments. For example, a low-intensity and autofocusing video camera is believed to be able to get a better image of the specimen than the one used in this study. A clearer picture can result in a better imaging analysis.
4. The concentration of the fluorescent powder in the specimens in this study is 60 ppm in weight. Although the specimens with the concentrations of fluorescent powder of 30 and 10 ppm were prepared, they could not be accurately analyzed due to insufficient fluorescence. The concentration of fluorescent powder can be reduced after improving the equipment used in HEVIS.
5. The method of choosing the size of the segments is preliminary, and may be refined in future work.

6. The software installed in the existing HEVIS can be improved to minimize the operating time.
7. In this study, standard deviation is employed to evaluate the homogeneity of a solidification product. A new scale might be proposed to indicate the specific homogeneity of a solidification product instead of standard deviation, such as mixing index.
8. For future applications, the video camera should be able to take the image of larger areas so that larger industrial treatment areas can be analyzed.

APPENDIX

Calculation Program in HEVIS

```
      PROGRAM KNOX.FOR
c   VEDIO IMAGE SYSTEM DRIVING PROGRAM ------ KNOX.FOR
c   THIS PROGRAM IS USED TO GENERATE FINAL RESULT DATA FILE
      INTEGER*4 KA(36),KB(36),KC(36),KD(36),KT1(36),KT2(36),KAS,
      INTEGER*4 KBS,KCS,KDS,
      INTEGER*4 NCC,NDD,KT1S,KT2S,KXX5,KXX6,KXX7,KXX8
      INTEGER NANS,I1,J1,NP1X,NP1Y,NP2X,NP2Y,NP3X,NP3Y,NP4X,NP4Y
      CHARACTER*20 FILENAME
c*  INPUT FOUR BOUNDARY POINTS
      WRITE(*,'(A)') '  ENTER DATA FILE NAME  '
      READ(*, '(A)') FILENAME
      WRITE(*,'(A,A)') ' INPUT FILE = ',FILENAME
      OPEN(3, FILE= FILENAME, STATUS='OLD', ACCESS='DIRECT',
     \FORM='UNFORMATTED', RECL=4)
      WRITE(*,'(A)')' PLEASE INPUT NP1,NP1Y,...,NP4Y,[8(I3,1X)]'
      READ(*,10)NP1X,NP1Y,NP2X,NP2Y,NP3X,NP3Y,NP4X,NP4Y
   10 FORMAT(8(I3,1X))
      WRITE(*,'(A)') ' NP1X,NP1Y,NP2X,NP2Y,NP3X,NP3Y,NP4X,NP4Y = '
      WRITE(*,11)NP1X,NP1Y,NP2X,NP2Y,NP3X,NP3Y,NP4X,NP4Y
   11 FORMAT(1X,I3,7I4)
      NP0X=(NP1X+NP3X)/2
      NP0Y=(NP2Y+NP4Y)/2
      K1 = NP0Y - NP1Y
      K2 = NP3Y - NP0Y
      K3 = NP0X - NP2X
      K4 = NP4X - NP0X
      NRAD = K1
      IF (K2 .LE. NRAD) NRAD = K2
      IF (K3 .LE. NRAD) NRAD = K3
      IF (K4 .LE. NRAD) NRAD = K4
      WRITE(*,'(1X,A,I3,3X,A,I3,5X,A,I3)') 'NP0X= ',NP0X,
     \'NP0Y= ',NP0Y,'NRAD= ',NRAD
      IF (NP0Y-NRAD .LT. 0) THEN
      WRITE(*,'(A)')'COORDINAT ERROR,DEFINED NEW CIRCLE SHAPE IS
     \ OVER THE TOP OF SCREEN. MOVE THE SAMPLE, TRY AGAIN!!!'
      GO TO 999
      ENDIF
      IF (NP0Y+NRAD .GT. 199) THEN
      WRITE(*,'(A)')'COORDINAT ERROR,DEFINED NEW CIRCLE SHAPE IS
     \ OVER THE BOTTOM OF SCREEN. MOVE THE SAMPLE, TRY AGAIN!!!'
      GO TO 999
      ENDIF
      IF (NP0X-NRAD .LT. 0) THEN
      WRITE(*,'(A)')'COORDINAT ERROR,DEFINED NEW CIRCLE SHAPE IS
     \ OVER THE LEFT SIDE OF SCREEN. MOVE THE SAMPLE, TRY AGAIN!!!'
      GO TO 999
      ENDIF
      IF (NP0X+NRAD .GT. 255) THEN
      WRITE(*,'(A)')'COORDINAT ERROR,DEFINED NEW CIRCLE SHAPE IS
     \ OVER THE RIGHT SIDE OF SCREEN. MOVE THE SAMPLE, TRY AGAIN!!!'
      GO TO 999
      ENDIF
      NDD=NRAD*NRAD
      WRITE(*,'(A)')' PLEASE INPUT IICL, IICH, &IICI? '
      READ(*,20) IICL, IICH, IICI
   20 FORMAT(I2,1X,I2,1X,I2)
      WRITE(*,'(1X,A,I2,3X,A,I2,5X,A,I2)') ' IICL= ',IICL,
     \'IICH= ',IICH,'IICI= ',IICI
      T1=0.1667*NRAD
      T2=0.2357*NRAD
      T3=0.2887*NRAD
      T4=0.3334*NRAD
```

```
      T5=0.3727*NRAD
      T6=0.4083*NRAD
      T7=0.4410*NRAD
      T8=0.4715*NRAD
      T9=0.5001*NRAD
      T10=0.5271*NRAD
      T11=0.5528*NRAD
      T12=0.5774*NRAD
      T13=0.6010*NRAD
      T14=0.6237*NRAD
      T15=0.6456*NRAD
      T16=0.6667*NRAD
      T17=0.6872*NRAD
      T18=0.7072*NRAD
      T19=0.7265*NRAD
      T20=0.7454*NRAD
      T21=0.7638*NRAD
      T22=0.7819*NRAD
      T23=0.7994*NRAD
      T24=0.8166*NRAD
      T25=0.8334*NRAD
      T26=0.8499*NRAD
      T27=0.8661*NRAD
      T28=0.8820*NRAD
      T29=0.8976*NRAD
      T30=0.9129*NRAD
      T31=0.9280*NRAD
      T32=0.9429*NRAD
      T33=0.9575*NRAD
      T34=0.9719*NRAD
      T35=0.9861*NRAD
      DO 998 IIC = IICL, IICH, IICI
      DO 30 I=1,36
        KA(I)=0
        KB(I)=0
        KC(I)=0
        KD(I)=0
        KT1(I)=0
        KT2(I)=0
   30 CONTINUE
c****************************L1  BEGIN****************************
      DO 140 I=NPOY-NRAD,NPOY
        DO 130 J=NPOX+1,NPOX+NRAD
      II=NPOY-I
      JJ=J-NPOX
      NCC=(II*II)+(JJ*JJ)
      IF(NCC .GT. NDD)GO TO 130
      III=(I*256)+J+1
      READ(3,REC=III)NANS
      BB=SQRT(REAL(II)**2+REAL(JJ)**2)
c******** COMPLETE THE PI SHAPE CALCULATION IN L1**********
      AA=ATAN(REAL(II)/REAL(JJ))*57.296
      IF(AA .LT. 10.) THEN
        KT1(1)=KT1(1)+1
        IF(NANS .LT. IIC) GO TO 100
        KA(1)=KA(1)+1
        KB(1)=KB(1)+NANS
      ELSEIF (AA .LT. 20.) THEN
        KT1(2)=KT1(2)+1
        IF(NANS .LT. IIC) GO TO 100
        KA(2)=KA(2)+1
        KB(2)=KB(2)+NANS
```

```
      ELSEIF (AA .LT. 30.) THEN
        KT1(3)=KT1(3)+1
        IF(NANS .LT. IIC) GO TO 100
        KA(3)=KA(3)+1
        KB(3)=KB(3)+NANS
      ELSEIF (AA .LT. 40.) THEN
        KT1(4)=KT1(4)+1
        IF(NANS .LT. IIC) GO TO 100
        KA(4)=KA(4)+1
        KB(4)=KB(4)+NANS
      ELSEIF (AA .LT. 50.) THEN
        KT1(5)=KT1(5)+1
        IF(NANS .LT. IIC) GO TO 100
        KA(5)=KA(5)+1
        KB(5)=KB(5)+NANS
      ELSEIF (AA .LT. 60.) THEN
        KT1(6)=KT1(6)+1
        IF(NANS .LT. IIC) GO TO 100
        KA(6)=KA(6)+1
        KB(6)=KB(6)+NANS
      ELSEIF (AA .LT. 70.) THEN
        KT1(7)=KT1(7)+1
        IF(NANS .LT. IIC) GO TO 100
        KA(7)=KA(7)+1
        KB(7)=KB(7)+NANS
      ELSEIF (AA .LT. 80.) THEN
        KT1(8)=KT1(8)+1
        IF(NANS .LT. IIC) GO TO 100
        KA(8)=KA(8)+1
        KB(8)=KB(8)+NANS
      ELSEIF (AA .LT. 90.) THEN
        KT1(9)=KT1(9)+1
        IF(NANS .LT. IIC) GO TO 100
        KA(9)=KA(9)+1
        KB(9)=KB(9)+NANS
      ELSE
      ENDIF
c********** COMPLETE THE RADIUS CALCULATION IN L1**********
  100 IF (BB .LE. T1) THEN
        KT2(1)=KT2(1)+1
        IF(NANS .LT. IIC) GO TO 130
        KC(1)=KC(1)+1
        KD(1)=KD(1)+NANS
      ELSEIF (BB .LE. T2) THEN
        KT2(2)=KT2(2)+1
        IF(NANS .LT. IIC) GO TO 130
        KC(2)=KC(2)+1
        KD(2)=KD(2)+NANS
      ELSEIF (BB .LE. T3) THEN
        KT2(3)=KT2(3)+1
        IF(NANS .LT. IIC) GO TO 130
        KC(3)=KC(3)+1
        KD(3)=KD(3)+NANS
      ELSEIF (BB .LE. T4) THEN
        KT2(4)=KT2(4)+1
        IF(NANS .LT. IIC) GO TO 130
        KC(4)=KC(4)+1
        KD(4)=KD(4)+NANS
      ELSEIF (BB .LE. T5) THEN
        KT2(5)=KT2(5)+1
        IF(NANS .LT. IIC) GO TO 130
        KC(5)=KC(5)+1
```

```
    KD(5)=KD(5)+NANS
  ELSEIF (BB .LE. T6) THEN
    KT2(6)=KT2(6)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(6)=KC(6)+1
    KD(6)=KD(6)+NANS
  ELSEIF (BB .LE. T7) THEN
    KT2(7)=KT2(7)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(7)=KC(7)+1
    KD(7)=KD(7)+NANS
  ELSEIF (BB .LE. T8) THEN
    KT2(8)=KT2(8)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(8)=KC(8)+1
    KD(8)=KD(8)+NANS
  ELSEIF (BB .LE. T9) THEN
    KT2(9)=KT2(9)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(9)=KC(9)+1
    KD(9)=KD(9)+NANS
  ELSEIF (BB .LE. T10) THEN
    KT2(10)=KT2(10)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(10)=KC(10)+1
    KD(10)=KD(10)+NANS
  ELSEIF (BB .LE. T11) THEN
    KT2(11)=KT2(11)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(11)=KC(11)+1
    KD(11)=KD(11)+NANS
  ELSEIF (BB .LE. T12) THEN
    KT2(12)=KT2(12)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(12)=KC(12)+1
    KD(12)=KD(12)+NANS
  ELSEIF (BB .LE. T13) THEN
    KT2(13)=KT2(13)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(13)=KC(13)+1
    KD(13)=KD(13)+NANS
  ELSEIF (BB .LE. T14) THEN
    KT2(14)=KT2(14)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(14)=KC(14)+1
    KD(14)=KD(14)+NANS
  ELSEIF (BB .LE. T15) THEN
    KT2(15)=KT2(15)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(15)=KC(15)+1
    KD(15)=KD(15)+NANS
  ELSEIF (BB .LE. T16) THEN
    KT2(16)=KT2(16)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(16)=KC(16)+1
    KD(16)=KD(16)+NANS
  ELSEIF (BB .LE. T17) THEN
    KT2(17)=KT2(17)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(17)=KC(17)+1
    KD(17)=KD(17)+NANS
  ELSEIF (BB .LE. T18) THEN
```

```
    KT2(18)=KT2(18)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(18)=KC(18)+1
    KD(18)=KD(18)+NANS
  ELSEIF (BB .LE. T19) THEN
    KT2(19)=KT2(19)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(19)=KC(19)+1
    KD(19)=KD(19)+NANS
  ELSEIF (BB .LE. T20) THEN
    KT2(20)=KT2(20)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(20)=KC(20)+1
    KD(20)=KD(20)+NANS
  ELSEIF (BB .LE. T21) THEN
    KT2(21)=KT2(21)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(21)=KC(21)+1
    KD(21)=KD(21)+NANS
  ELSEIF (BB .LE. T22) THEN
    KT2(22)=KT2(22)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(22)=KC(22)+1
    KD(22)=KD(22)+NANS
  ELSEIF (BB .LE. T23) THEN
    KT2(23)=KT2(23)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(23)=KC(23)+1
    KD(23)=KD(23)+NANS
  ELSEIF (BB .LE. T24) THEN
    KT2(24)=KT2(24)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(24)=KC(24)+1
    KD(24)=KD(24)+NANS
  ELSEIF (BB .LE. T25) THEN
    KT2(25)=KT2(25)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(25)=KC(25)+1
    KD(25)=KD(25)+NANS
  ELSEIF (BB .LE. T26) THEN
    KT2(26)=KT2(26)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(26)=KC(26)+1
    KD(26)=KD(26)+NANS
  ELSEIF (BB .LE. T27) THEN
    KT2(27)=KT2(27)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(27)=KC(27)+1
    KD(27)=KD(27)+NANS
  ELSEIF (BB .LE. T28) THEN
    KT2(28)=KT2(28)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(28)=KC(28)+1
    KD(28)=KD(28)+NANS
  ELSEIF (BB .LE. T29) THEN
    KT2(29)=KT2(29)+1
    IF(NANS .LT. IIC) GO TO 130
    KC(29)=KC(29)+1
    KD(29)=KD(29)+NANS
  ELSEIF (BB .LE. T30) THEN
    KT2(30)=KT2(30)+1
    IF(NANS .LT. IIC) GO TO 130
```

```
          KC(30)=KC(30)+1
          KD(30)=KD(30)+NANS
        ELSEIF (BB .LE. T31) THEN
          KT2(31)=KT2(31)+1
          IF(NANS .LT. IIC) GO TO 130
          KC(31)=KC(31)+1
          KD(31)=KD(31)+NANS
        ELSEIF (BB .LE. T32) THEN
          KT2(32)=KT2(32)+1
          IF(NANS .LT. IIC) GO TO 130
          KC(32)=KC(32)+1
          KD(32)=KD(32)+NANS
        ELSEIF (BB .LE. T33) THEN
          KT2(33)=KT2(33)+1
          IF(NANS .LT. IIC) GO TO 130
          KC(33)=KC(33)+1
          KD(33)=KD(33)+NANS
        ELSEIF (BB .LE. T34) THEN
          KT2(34)=KT2(34)+1
          IF(NANS .LT. IIC) GO TO 130
          KC(34)=KC(34)+1
          KD(34)=KD(34)+NANS
        ELSEIF (BB .LE. T35) THEN
          KT2(35)=KT2(35)+1
          IF(NANS .LT. IIC) GO TO 130
          KC(35)=KC(35)+1
          KD(35)=KD(35)+NANS
        ELSE
          KT2(36)=KT2(36)+1
          IF(NANS .LT. IIC) GO TO 130
          KC(36)=KC(36)+1
          KD(36)=KD(36)+NANS
        ENDIF
  130     CONTINUE
  140 CONTINUE
c**************************L1  END ******************************
c**************************L2  BEGIN ****************************
      DO 180 I=NPOY-NRAD,NPOY-1
        DO 170 J=NPOX-NRAD,NPOX
      II=NPOY-I
      JJ=J-NPOX
      NCC=(II*II)+(JJ*JJ)
      IF(NCC .GT. NDD)GO TO 170
      III=(I*256)+J+1
      READ(3,REC=III)NANS
      BB=SQRT(REAL(II)**2+REAL(JJ)**2)
c******** COMPLETE THE PI SHAPE CALCULATION IN L2**********
      IF (JJ .EQ. 0) GO TO 166
      AA=-ATAN(REAL(II)/REAL(JJ))*57.296
      IF(AA .GT. 80.) THEN
        KT1(10)=KT1(10)+1
        IF(NANS .LT. IIC)GO TO 167
        KA(10)=KA(10)+1
        KB(10)=KB(10)+NANS
      ELSEIF (AA .GT. 70.) THEN
        KT1(11)=KT1(11)+1
        IF(NANS .LT. IIC)GO TO 167
        KA(11)=KA(11)+1
        KB(11)=KB(11)+NANS
      ELSEIF (AA .GT. 60.) THEN
        KT1(12)=KT1(12)+1
        IF(NANS .LT. IIC)GO TO 167
```

```
  KD(18)=KD(18)+NANS
ELSEIF (BB .LE. T19) THEN
  KT2(19)=KT2(19)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(19)=KC(19)+1
  KD(19)=KD(19)+NANS
ELSEIF (BB .LE. T20) THEN
  KT2(20)=KT2(20)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(20)=KC(20)+1
  KD(20)=KD(20)+NANS
ELSEIF (BB .LE. T21) THEN
  KT2(21)=KT2(21)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(21)=KC(21)+1
  KD(21)=KD(21)+NANS
ELSEIF (BB .LE. T22) THEN
  KT2(22)=KT2(22)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(22)=KC(22)+1
  KD(22)=KD(22)+NANS
ELSEIF (BB .LE. T23) THEN
  KT2(23)=KT2(23)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(23)=KC(23)+1
  KD(23)=KD(23)+NANS
ELSEIF (BB .LE. T24) THEN
  KT2(24)=KT2(24)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(24)=KC(24)+1
  KD(24)=KD(24)+NANS
ELSEIF (BB .LE. T25) THEN
  KT2(25)=KT2(25)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(25)=KC(25)+1
  KD(25)=KD(25)+NANS
ELSEIF (BB .LE. T26) THEN
  KT2(26)=KT2(26)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(26)=KC(26)+1
  KD(26)=KD(26)+NANS
ELSEIF (BB .LE. T27) THEN
  KT2(27)=KT2(27)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(27)=KC(27)+1
  KD(27)=KD(27)+NANS
ELSEIF (BB .LE. T28) THEN
  KT2(28)=KT2(28)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(28)=KC(28)+1
  KD(28)=KD(28)+NANS
ELSEIF (BB .LE. T29) THEN
  KT2(29)=KT2(29)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(29)=KC(29)+1
  KD(29)=KD(29)+NANS
ELSEIF (BB .LE. T30) THEN
  KT2(30)=KT2(30)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(30)=KC(30)+1
  KD(30)=KD(30)+NANS
ELSEIF (BB .LE. T31) THEN
```

```
          KT2(31)=KT2(31)+1
          IF(NANS .LT. IIC) GO TO 240
          KC(31)=KC(31)+1
          KD(31)=KD(31)+NANS
        ELSEIF (BB .LE. T32) THEN
          KT2(32)=KT2(32)+1
          IF(NANS .LT. IIC) GO TO 240
          KC(32)=KC(32)+1
          KD(32)=KD(32)+NANS
        ELSEIF (BB .LE. T33) THEN
          KT2(33)=KT2(33)+1
          IF(NANS .LT. IIC) GO TO 240
          KC(33)=KC(33)+1
          KD(33)=KD(33)+NANS
        ELSEIF (BB .LE. T34) THEN
          KT2(34)=KT2(34)+1
          IF(NANS .LT. IIC) GO TO 240
          KC(34)=KC(34)+1
          KD(34)=KD(34)+NANS
        ELSEIF (BB .LE. T35) THEN
          KT2(35)=KT2(35)+1
          IF(NANS .LT. IIC) GO TO 240
          KC(35)=KC(35)+1
          KD(35)=KD(35)+NANS
        ELSE
          KT2(36)=KT2(36)+1
          IF(NANS .LT. IIC) GO TO 240
          KC(36)=KC(36)+1
          KD(36)=KD(36)+NANS
        ENDIF
  240      CONTINUE
  250 CONTINUE
C*************************L4  END ***********************************
C**************************  STATISTICS  *************************
      KAS=0
      KBS=0
      KCS=0
      KDS=0
      KT1S=0
      KT2S=0
      DO 500 I=1,36
        KAS=KAS+KA(I)
        KBS=KBS+KB(I)
        KCS=KCS+KC(I)
        KDS=KDS+KD(I)
        KT1S=KT1S+KT1(I)
        KT2S=KT2S+KT2(I)
  500 CONTINUE
      IF (KAS .LE. 0) THEN
      WRITE(*,'(A)')' WARNING !!! KAS < 0, TRY OTHER IIC AGAIN!'
      WRITE(*,'(1X,A,I3)') ' WHEN IIC= ', IIC
      GO TO 999
      ENDIF
      IF (KBS .LE. 0) THEN
      WRITE(*,'(A)')' WARNING !!! KBS < 0, TRY OTHER IIC AGAIN!'
      WRITE(*,'(1X,A,I3)') ' WHEN IIC= ', IIC
      GO TO 999
      ENDIF
      IF (KCS .LE. 0) THEN
      WRITE(*,'(A)')' WARNING !!! KCS < 0, TRY OTHER IIC AGAIN!'
      WRITE(*,'(1X,A,I3)') ' WHEN IIC= ', IIC
      GO TO 999
```

```
        KA(12)=KA(12)+1
        KB(12)=KB(12)+NANS
      ELSEIF (AA .GT. 50.) THEN
        KT1(13)=KT1(13)+1
        IF(NANS .LT. IIC)GO TO 167
        KA(13)=KA(13)+1
        KB(13)=KB(13)+NANS
      ELSEIF (AA .GT. 40.) THEN
        KT1(14)=KT1(14)+1
        IF(NANS .LT. IIC)GO TO 167
        KA(14)=KA(14)+1
        KB(14)=KB(14)+NANS
      ELSEIF (AA .GT. 30.) THEN
        KT1(15)=KT1(15)+1
        IF(NANS .LT. IIC)GO TO 167
        KA(15)=KA(15)+1
        KB(15)=KB(15)+NANS
      ELSEIF (AA .GT. 20.) THEN
        KT1(16)=KT1(16)+1
        IF(NANS .LT. IIC)GO TO 167
        KA(16)=KA(16)+1
        KB(16)=KB(16)+NANS
      ELSEIF (AA .GT. 10.) THEN
        KT1(17)=KT1(17)+1
        IF(NANS .LT. IIC)GO TO 167
        KA(17)=KA(17)+1
        KB(17)=KB(17)+NANS
      ELSE
        KT1(18)=KT1(18)+1
        IF(NANS .LT. IIC)GO TO 167
        KA(18)=KA(18)+1
        KB(18)=KB(18)+NANS
      ENDIF
      GO TO 167
  166 KT1(10)=KT1(10)+1
      IF(NANS .LT. IIC)GO TO 167
      KA(10)=KA(10)+1
      KB(10)=KB(10)+NANS
C********** COMPLETE THE RADIUS CALCULATION IN L2**********
  167 IF (BB .LE. T1) THEN
        KT2(1)=KT2(1)+1
        IF(NANS .LT. IIC) GO TO 170
        KC(1)=KC(1)+1
        KD(1)=KD(1)+NANS
      ELSEIF (BB .LE. T2) THEN
        KT2(2)=KT2(2)+1
        IF(NANS .LT. IIC) GO TO 170
        KC(2)=KC(2)+1
        KD(2)=KD(2)+NANS
      ELSEIF (BB .LE. T3) THEN
        KT2(3)=KT2(3)+1
        IF(NANS .LT. IIC) GO TO 170
        KC(3)=KC(3)+1
        KD(3)=KD(3)+NANS
      ELSEIF (BB .LE. T4) THEN
        KT2(4)=KT2(4)+1
        IF(NANS .LT. IIC) GO TO 170
        KC(4)=KC(4)+1
        KD(4)=KD(4)+NANS
      ELSEIF (BB .LE. T5) THEN
        KT2(5)=KT2(5)+1
        IF(NANS .LT. IIC) GO TO 170
```

```
   KC(5)=KC(5)+1
   KD(5)=KD(5)+NANS
 ELSEIF (BB .LE. T6) THEN
   KT2(6)=KT2(6)+1
   IF(NANS .LT. IIC) GO TO 170
   KC(6)=KC(6)+1
   KD(6)=KD(6)+NANS
 ELSEIF (BB .LE. T7) THEN
   KT2(7)=KT2(7)+1
   IF(NANS .LT. IIC) GO TO 170
   KC(7)=KC(7)+1
   KD(7)=KD(7)+NANS
 ELSEIF (BB .LE. T8) THEN
   KT2(8)=KT2(8)+1
   IF(NANS .LT. IIC) GO TO 170
   KC(8)=KC(8)+1
   KD(8)=KD(8)+NANS
 ELSEIF (BB .LE. T9) THEN
   KT2(9)=KT2(9)+1
   IF(NANS .LT. IIC) GO TO 170
   KC(9)=KC(9)+1
   KD(9)=KD(9)+NANS
 ELSEIF (BB .LE. T10) THEN
   KT2(10)=KT2(10)+1
   IF(NANS .LT. IIC) GO TO 170
   KC(10)=KC(10)+1
   KD(10)=KD(10)+NANS
 ELSEIF (BB .LE. T11) THEN
   KT2(11)=KT2(11)+1
   IF(NANS .LT. IIC) GO TO 170
   KC(11)=KC(11)+1
   KD(11)=KD(11)+NANS
 ELSEIF (BB .LE. T12) THEN
   KT2(12)=KT2(12)+1
   IF(NANS .LT. IIC) GO TO 170
   KC(12)=KC(12)+1
   KD(12)=KD(12)+NANS
 ELSEIF (BB .LE. T13) THEN
   KT2(13)=KT2(13)+1
   IF(NANS .LT. IIC) GO TO 170
   KC(13)=KC(13)+1
   KD(13)=KD(13)+NANS
 ELSEIF (BB .LE. T14) THEN
   KT2(14)=KT2(14)+1
   IF(NANS .LT. IIC) GO TO 170
   KC(14)=KC(14)+1
   KD(14)=KD(14)+NANS
 ELSEIF (BB .LE. T15) THEN
   KT2(15)=KT2(15)+1
   IF(NANS .LT. IIC) GO TO 170
   KC(15)=KC(15)+1
   KD(15)=KD(15)+NANS
 ELSEIF (BB .LE. T16) THEN
   KT2(16)=KT2(16)+1
   IF(NANS .LT. IIC) GO TO 170
   KC(16)=KC(16)+1
   KD(16)=KD(16)+NANS
 ELSEIF (BB .LE. T17) THEN
   KT2(17)=KT2(17)+1
   IF(NANS .LT. IIC) GO TO 170
   KC(17)=KC(17)+1
   KD(17)=KD(17)+NANS
```

```
ELSEIF (BB .LE. T18) THEN
  KT2(18)=KT2(18)+1
  IF(NANS .LT. IIC) GO TO 170
  KC(18)=KC(18)+1
  KD(18)=KD(18)+NANS
ELSEIF (BB .LE. T19) THEN
  KT2(19)=KT2(19)+1
  IF(NANS .LT. IIC) GO TO 170
  KC(19)=KC(19)+1
  KD(19)=KD(19)+NANS
ELSEIF (BB .LE. T20) THEN
  KT2(20)=KT2(20)+1
  IF(NANS .LT. IIC) GO TO 170
  KC(20)=KC(20)+1
  KD(20)=KD(20)+NANS
ELSEIF (BB .LE. T21) THEN
  KT2(21)=KT2(21)+1
  IF(NANS .LT. IIC) GO TO 170
  KC(21)=KC(21)+1
  KD(21)=KD(21)+NANS
ELSEIF (BB .LE. T22) THEN
  KT2(22)=KT2(22)+1
  IF(NANS .LT. IIC) GO TO 170
  KC(22)=KC(22)+1
  KD(22)=KD(22)+NANS
ELSEIF (BB .LE. T23) THEN
  KT2(23)=KT2(23)+1
  IF(NANS .LT. IIC) GO TO 170
  KC(23)=KC(23)+1
  KD(23)=KD(23)+NANS
ELSEIF (BB .LE. T24) THEN
  KT2(24)=KT2(24)+1
  IF(NANS .LT. IIC) GO TO 170
  KC(24)=KC(24)+1
  KD(24)=KD(24)+NANS
ELSEIF (BB .LE. T25) THEN
  KT2(25)=KT2(25)+1
  IF(NANS .LT. IIC) GO TO 170
  KC(25)=KC(25)+1
  KD(25)=KD(25)+NANS
ELSEIF (BB .LE. T26) THEN
  KT2(26)=KT2(26)+1
  IF(NANS .LT. IIC) GO TO 170
  KC(26)=KC(26)+1
  KD(26)=KD(26)+NANS
ELSEIF (BB .LE. T27) THEN
  KT2(27)=KT2(27)+1
  IF(NANS .LT. IIC) GO TO 170
  KC(27)=KC(27)+1
  KD(27)=KD(27)+NANS
ELSEIF (BB .LE. T28) THEN
  KT2(28)=KT2(28)+1
  IF(NANS .LT. IIC) GO TO 170
  KC(28)=KC(28)+1
  KD(28)=KD(28)+NANS
ELSEIF (BB .LE. T29) THEN
  KT2(29)=KT2(29)+1
  IF(NANS .LT. IIC) GO TO 170
  KC(29)=KC(29)+1
  KD(29)=KD(29)+NANS
ELSEIF (BB .LE. T30) THEN
  KT2(30)=KT2(30)+1
```

```
          IF(NANS .LT. IIC) GO TO 170
          KC(30)=KC(30)+1
          KD(30)=KD(30)+NANS
        ELSEIF (BB .LE. T31) THEN
          KT2(31)=KT2(31)+1
          IF(NANS .LT. IIC) GO TO 170
          KC(31)=KC(31)+1
          KD(31)=KD(31)+NANS
        ELSEIF (BB .LE. T32) THEN
          KT2(32)=KT2(32)+1
          IF(NANS .LT. IIC) GO TO 170
          KC(32)=KC(32)+1
          KD(32)=KD(32)+NANS
        ELSEIF (BB .LE. T33) THEN
          KT2(33)=KT2(33)+1
          IF(NANS .LT. IIC) GO TO 170
          KC(33)=KC(33)+1
          KD(33)=KD(33)+NANS
        ELSEIF (BB .LE. T34) THEN
          KT2(34)=KT2(34)+1
          IF(NANS .LT. IIC) GO TO 170
          KC(34)=KC(34)+1
          KD(34)=KD(34)+NANS
        ELSEIF (BB .LE. T35) THEN
          KT2(35)=KT2(35)+1
          IF(NANS .LT. IIC) GO TO 170
          KC(35)=KC(35)+1
          KD(35)=KD(35)+NANS
        ELSE
          KT2(36)=KT2(36)+1
          IF(NANS .LT. IIC) GO TO 170
          KC(36)=KC(36)+1
          KD(36)=KD(36)+NANS
        ENDIF
  170     CONTINUE
  180 CONTINUE
c***************************L2  END *******************************
c***************************L3  BEGIN *****************************
      DO 220 I=NPOY,NPOY+NRAD
        DO 210 J=NPOX-NRAD,NPOX-1
      II=NPOY-I
      JJ=J-NPOX
      NCC=(II*II)+(JJ*JJ)
      IF(NCC .GT. NDD)GO TO 210
      III=(I*256)+J+1
      READ(3,REC=III)NANS
      BB=SQRT(REAL(II)**2+REAL(JJ)**2)
c******** COMPLETE THE PI SHAPE CALCULATION IN L3**********
      AA=ATAN(REAL(II)/REAL(JJ))*57.296
      IF(AA .LT. 10.) THEN
        KT1(19)=KT1(19)+1
        IF(NANS .LT. IIC)GO TO 200
        KA(19)=KA(19)+1
        KB(19)=KB(19)+NANS
      ELSEIF (AA .LT. 20.) THEN
        KT1(20)=KT1(20)+1
        IF(NANS .LT. IIC)GO TO 200
        KA(20)=KA(20)+1
        KB(20)=KB(20)+NANS
      ELSEIF (AA .LT. 30.) THEN
        KT1(21)=KT1(21)+1
        IF(NANS .LT. IIC)GO TO 200
```

```
          KA(21)=KA(21)+1
          KB(21)=KB(21)+NANS
        ELSEIF (AA .LT. 40.) THEN
          KT1(22)=KT1(22)+1
          IF(NANS .LT. IIC)GO TO 200
          KA(22)=KA(22)+1
          KB(22)=KB(22)+NANS
        ELSEIF (AA .LT. 50.) THEN
          KT1(23)=KT1(23)+1
          IF(NANS .LT. IIC)GO TO 200
          KA(23)=KA(23)+1
          KB(23)=KB(23)+NANS
        ELSEIF (AA .LT. 60.) THEN
          KT1(24)=KT1(24)+1
          IF(NANS .LT. IIC)GO TO 200
          KA(24)=KA(24)+1
          KB(24)=KB(24)+NANS
        ELSEIF (AA .LT. 70.) THEN
          KT1(25)=KT1(25)+1
          IF(NANS .LT. IIC)GO TO 200
          KA(25)=KA(25)+1
          KB(25)=KB(25)+NANS
        ELSEIF (AA .LT. 80.) THEN
          KT1(26)=KT1(26)+1
          IF(NANS .LT. IIC)GO TO 200
          KA(26)=KA(26)+1
          KB(26)=KB(26)+NANS
        ELSE
          KT1(27)=KT1(27)+1
          IF(NANS .LT. IIC)GO TO 200
          KA(27)=KA(27)+1
          KB(27)=KB(27)+NANS
        ENDIF
c********** COMPLETE THE RADIUS CALCULATION IN L3**********
    200 IF (BB .LE. T1) THEN
          KT2(1)=KT2(1)+1
          IF(NANS .LT. IIC) GO TO 210
          KC(1)=KC(1)+1
          KD(1)=KD(1)+NANS
        ELSEIF (BB .LE. T2) THEN
          KT2(2)=KT2(2)+1
          IF(NANS .LT. IIC) GO TO 210
          KC(2)=KC(2)+1
          KD(2)=KD(2)+NANS
        ELSEIF (BB .LE. T3) THEN
          KT2(3)=KT2(3)+1
          IF(NANS .LT. IIC) GO TO 210
          KC(3)=KC(3)+1
          KD(3)=KD(3)+NANS
        ELSEIF (BB .LE. T4) THEN
          KT2(4)=KT2(4)+1
          IF(NANS .LT. IIC) GO TO 210
          KC(4)=KC(4)+1
          KD(4)=KD(4)+NANS
        ELSEIF (BB .LE. T5) THEN
          KT2(5)=KT2(5)+1
          IF(NANS .LT. IIC) GO TO 210
          KC(5)=KC(5)+1
          KD(5)=KD(5)+NANS
        ELSEIF (BB .LE. T6) THEN
          KT2(6)=KT2(6)+1
          IF(NANS .LT. IIC) GO TO 210
```

```
    KC(6)=KC(6)+1
    KD(6)=KD(6)+NANS
  ELSEIF (BB .LE. T7) THEN
    KT2(7)=KT2(7)+1
    IF(NANS .LT. IIC) GO TO 210
    KC(7)=KC(7)+1
    KD(7)=KD(7)+NANS
  ELSEIF (BB .LE. T8) THEN
    KT2(8)=KT2(8)+1
    IF(NANS .LT. IIC) GO TO 210
    KC(8)=KC(8)+1
    KD(8)=KD(8)+NANS
  ELSEIF (BB .LE. T9) THEN
    KT2(9)=KT2(9)+1
    IF(NANS .LT. IIC) GO TO 210
    KC(9)=KC(9)+1
    KD(9)=KD(9)+NANS
  ELSEIF (BB .LE. T10) THEN
    KT2(10)=KT2(10)+1
    IF(NANS .LT. IIC) GO TO 210
    KC(10)=KC(10)+1
    KD(10)=KD(10)+NANS
  ELSEIF (BB .LE. T11) THEN
    KT2(11)=KT2(11)+1
    IF(NANS .LT. IIC) GO TO 210
    KC(11)=KC(11)+1
    KD(11)=KD(11)+NANS
  ELSEIF (BB .LE. T12) THEN
    KT2(12)=KT2(12)+1
    IF(NANS .LT. IIC) GO TO 210
    KC(12)=KC(12)+1
    KD(12)=KD(12)+NANS
  ELSEIF (BB .LE. T13) THEN
    KT2(13)=KT2(13)+1
    IF(NANS .LT. IIC) GO TO 210
    KC(13)=KC(13)+1
    KD(13)=KD(13)+NANS
  ELSEIF (BB .LE. T14) THEN
    KT2(14)=KT2(14)+1
    IF(NANS .LT. IIC) GO TO 210
    KC(14)=KC(14)+1
    KD(14)=KD(14)+NANS
  ELSEIF (BB .LE. T15) THEN
    KT2(15)=KT2(15)+1
    IF(NANS .LT. IIC) GO TO 210
    KC(15)=KC(15)+1
    KD(15)=KD(15)+NANS
  ELSEIF (BB .LE. T16) THEN
    KT2(16)=KT2(16)+1
    IF(NANS .LT. IIC) GO TO 210
    KC(16)=KC(16)+1
    KD(16)=KD(16)+NANS
  ELSEIF (BB .LE. T17) THEN
    KT2(17)=KT2(17)+1
    IF(NANS .LT. IIC) GO TO 210
    KC(17)=KC(17)+1
    KD(17)=KD(17)+NANS
  ELSEIF (BB .LE. T18) THEN
    KT2(18)=KT2(18)+1
    IF(NANS .LT. IIC) GO TO 210
    KC(18)=KC(18)+1
    KD(18)=KD(18)+NANS
```

```
ELSEIF (BB .LE. T19) THEN
  KT2(19)=KT2(19)+1
  IF(NANS .LT. IIC) GO TO 210
  KC(19)=KC(19)+1
  KD(19)=KD(19)+NANS
ELSEIF (BB .LE. T20) THEN
  KT2(20)=KT2(20)+1
  IF(NANS .LT. IIC) GO TO 210
  KC(20)=KC(20)+1
  KD(20)=KD(20)+NANS
ELSEIF (BB .LE. T21) THEN
  KT2(21)=KT2(21)+1
  IF(NANS .LT. IIC) GO TO 210
  KC(21)=KC(21)+1
  KD(21)=KD(21)+NANS
ELSEIF (BB .LE. T22) THEN
  KT2(22)=KT2(22)+1
  IF(NANS .LT. IIC) GO TO 210
  KC(22)=KC(22)+1
  KD(22)=KD(22)+NANS
ELSEIF (BB .LE. T23) THEN
  KT2(23)=KT2(23)+1
  IF(NANS .LT. IIC) GO TO 210
  KC(23)=KC(23)+1
  KD(23)=KD(23)+NANS
ELSEIF (BB .LE. T24) THEN
  KT2(24)=KT2(24)+1
  IF(NANS .LT. IIC) GO TO 210
  KC(24)=KC(24)+1
  KD(24)=KD(24)+NANS
ELSEIF (BB .LE. T25) THEN
  KT2(25)=KT2(25)+1
  IF(NANS .LT. IIC) GO TO 210
  KC(25)=KC(25)+1
  KD(25)=KD(25)+NANS
ELSEIF (BB .LE. T26) THEN
  KT2(26)=KT2(26)+1
  IF(NANS .LT. IIC) GO TO 210
  KC(26)=KC(26)+1
  KD(26)=KD(26)+NANS
ELSEIF (BB .LE. T27) THEN
  KT2(27)=KT2(27)+1
  IF(NANS .LT. IIC) GO TO 210
  KC(27)=KC(27)+1
  KD(27)=KD(27)+NANS
ELSEIF (BB .LE. T28) THEN
  KT2(28)=KT2(28)+1
  IF(NANS .LT. IIC) GO TO 210
  KC(28)=KC(28)+1
  KD(28)=KD(28)+NANS
ELSEIF (BB .LE. T29) THEN
  KT2(29)=KT2(29)+1
  IF(NANS .LT. IIC) GO TO 210
  KC(29)=KC(29)+1
  KD(29)=KD(29)+NANS
ELSEIF (BB .LE. T30) THEN
  KT2(30)=KT2(30)+1
  IF(NANS .LT. IIC) GO TO 210
  KC(30)=KC(30)+1
  KD(30)=KD(30)+NANS
ELSEIF (BB .LE. T31) THEN
  KT2(31)=KT2(31)+1
```

```
        IF(NANS .LT. IIC) GO TO 210
        KC(31)=KC(31)+1
        KD(31)=KD(31)+NANS
      ELSEIF (BB .LE. T32) THEN
        KT2(32)=KT2(32)+1
        IF(NANS .LT. IIC) GO TO 210
        KC(32)=KC(32)+1
        KD(32)=KD(32)+NANS
      ELSEIF (BB .LE. T33) THEN
        KT2(33)=KT2(33)+1
        IF(NANS .LT. IIC) GO TO 210
        KC(33)=KC(33)+1
        KD(33)=KD(33)+NANS
      ELSEIF (BB .LE. T34) THEN
        KT2(34)=KT2(34)+1
        IF(NANS .LT. IIC) GO TO 210
        KC(34)=KC(34)+1
        KD(34)=KD(34)+NANS
      ELSEIF (BB .LE. T35) THEN
        KT2(35)=KT2(35)+1
        IF(NANS .LT. IIC) GO TO 210
        KC(35)=KC(35)+1
        KD(35)=KD(35)+NANS
      ELSE
        KT2(36)=KT2(36)+1
        IF(NANS .LT. IIC) GO TO 210
        KC(36)=KC(36)+1
        KD(36)=KD(36)+NANS
      ENDIF
  210     CONTINUE
  220 CONTINUE
c**************************L3  END ******************************
c**************************L4  BEGIN ****************************
      DO 250 I=NPOY+1,NPOY+NRAD
        DO 240 J=NPOX,NPOX+NRAD
      II=NPOY-I
      JJ=J-NPOX
      NCC=(II*II)+(JJ*JJ)
      IF(NCC .GT. NDD)GO TO 240
      III=(I*256)+J+1
      READ(3,REC=III)NANS
      BB=SQRT(REAL(II)**2+REAL(JJ)**2)
c******** COMPLETE THE PI SHAPE CALCULATION IN L4**********
      IF (JJ .EQ. 0) GO TO 236
      AA=-ATAN(REAL(II)/REAL(JJ))*57.296
      IF(AA .GT. 80.) THEN
        KT1(28)=KT1(28)+1
        IF(NANS .LT. IIC)GO TO 237
        KA(28)=KA(28)+1
        KB(28)=KB(28)+NANS
      ELSEIF (AA .GT. 70.) THEN
        KT1(29)=KT1(29)+1
        IF(NANS .LT. IIC)GO TO 237
        KA(29)=KA(29)+1
        KB(29)=KB(29)+NANS
      ELSEIF (AA .GT. 60.) THEN
        KT1(30)=KT1(30)+1
        IF(NANS .LT. IIC)GO TO 237
        KA(30)=KA(30)+1
        KB(30)=KB(30)+NANS
      ELSEIF (AA .GT. 50.) THEN
        KT1(31)=KT1(31)+1
```

```
        IF(NANS .LT. IIC)GO TO 237
        KA(31)=KA(31)+1
        KB(31)=KB(31)+NANS
      ELSEIF (AA .GT. 40.) THEN
        KT1(32)=KT1(32)+1
        IF(NANS .LT. IIC)GO TO 237
        KA(32)=KA(32)+1
        KB(32)=KB(32)+NANS
      ELSEIF (AA .GT. 30.) THEN
        KT1(33)=KT1(33)+1
        IF(NANS .LT. IIC)GO TO 237
        KA(33)=KA(33)+1
        KB(33)=KB(33)+NANS
      ELSEIF (AA .GT. 20.) THEN
        KT1(34)=KT1(34)+1
        IF(NANS .LT. IIC)GO TO 237
        KA(34)=KA(34)+1
        KB(34)=KB(34)+NANS
      ELSEIF (AA .GT. 10.) THEN
        KT1(35)=KT1(35)+1
        IF(NANS .LT. IIC)GO TO 237
        KA(35)=KA(35)+1
        KB(35)=KB(35)+NANS
      ELSE
        KT1(36)=KT1(36)+1
        IF(NANS .LT. IIC)GO TO 237
        KA(36)=KA(36)+1
        KB(36)=KB(36)+NANS
      ENDIF
      GO TO 237
  236 KT1(28)=KT1(28)+1
      IF(NANS .LT. IIC)GO TO 237
      KA(28)=KA(28)+1
      KB(28)=KB(28)+NANS
c********** COMPLETE THE RADIUS CALCULATION IN L4**********
  237 IF (BB .LE. T1) THEN
        KT2(1)=KT2(1)+1
        IF(NANS .LT. IIC) GO TO 240
        KC(1)=KC(1)+1
        KD(1)=KD(1)+NANS
      ELSEIF (BB .LE. T2) THEN
        KT2(2)=KT2(2)+1
        IF(NANS .LT. IIC) GO TO 240
        KC(2)=KC(2)+1
        KD(2)=KD(2)+NANS
      ELSEIF (BB .LE. T3) THEN
        KT2(3)=KT2(3)+1
        IF(NANS .LT. IIC) GO TO 240
        KC(3)=KC(3)+1
        KD(3)=KD(3)+NANS
      ELSEIF (BB .LE. T4) THEN
        KT2(4)=KT2(4)+1
        IF(NANS .LT. IIC) GO TO 240
        KC(4)=KC(4)+1
        KD(4)=KD(4)+NANS
      ELSEIF (BB .LE. T5) THEN
        KT2(5)=KT2(5)+1
        IF(NANS .LT. IIC) GO TO 240
        KC(5)=KC(5)+1
        KD(5)=KD(5)+NANS
      ELSEIF (BB .LE. T6) THEN
        KT2(6)=KT2(6)+1
```

```
  IF(NANS .LT. IIC) GO TO 240
  KC(6)=KC(6)+1
  KD(6)=KD(6)+NANS
ELSEIF (BB .LE. T7) THEN
  KT2(7)=KT2(7)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(7)=KC(7)+1
  KD(7)=KD(7)+NANS
ELSEIF (BB .LE. T8) THEN
  KT2(8)=KT2(8)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(8)=KC(8)+1
  KD(8)=KD(8)+NANS
ELSEIF (BB .LE. T9) THEN
  KT2(9)=KT2(9)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(9)=KC(9)+1
  KD(9)=KD(9)+NANS
ELSEIF (BB .LE. T10) THEN
  KT2(10)=KT2(10)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(10)=KC(10)+1
  KD(10)=KD(10)+NANS
ELSEIF (BB .LE. T11) THEN
  KT2(11)=KT2(11)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(11)=KC(11)+1
  KD(11)=KD(11)+NANS
ELSEIF (BB .LE. T12) THEN
  KT2(12)=KT2(12)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(12)=KC(12)+1
  KD(12)=KD(12)+NANS
ELSEIF (BB .LE. T13) THEN
  KT2(13)=KT2(13)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(13)=KC(13)+1
  KD(13)=KD(13)+NANS
ELSEIF (BB .LE. T14) THEN
  KT2(14)=KT2(14)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(14)=KC(14)+1
  KD(14)=KD(14)+NANS
ELSEIF (BB .LE. T15) THEN
  KT2(15)=KT2(15)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(15)=KC(15)+1
  KD(15)=KD(15)+NANS
ELSEIF (BB .LE. T16) THEN
  KT2(16)=KT2(16)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(16)=KC(16)+1
  KD(16)=KD(16)+NANS
ELSEIF (BB .LE. T17) THEN
  KT2(17)=KT2(17)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(17)=KC(17)+1
  KD(17)=KD(17)+NANS
ELSEIF (BB .LE. T18) THEN
  KT2(18)=KT2(18)+1
  IF(NANS .LT. IIC) GO TO 240
  KC(18)=KC(18)+1
```

```
      ENDIF
      IF (KDS .LE. 0) THEN
      WRITE(*,'(A)')' WARNING !!! KDS < 0, TRY OTHER IIC AGAIN!'
      WRITE(*,'(1X,A,I3)') ' WHEN IIC= ', IIC
      GO TO 999
      ENDIF
      AKAS36=KAS/36.
      AKBS36=KBS/36.
      AKCS36=KCS/36.
      AKDS36=KDS/36.
      AT1S36=KT1S/36.
      AT2S36=KT2S/36.
      SUMA36=0.
      SUMB36=0.
      SUMC36=0.
      SUMD36=0.
      DO 510 I=1,36
      SUMA36=SUMA36+((((KA(I)*AT1S36)/(AKAS36*KT1(I)))-1.)**2)
      SUMB36=SUMB36+((((KB(I)*AT1S36)/(AKBS36*KT1(I)))-1.)**2)
      SUMC36=SUMC36+((((KC(I)*AT2S36)/(AKCS36*KT2(I)))-1.)**2)
      SUMD36=SUMD36+((((KD(I)*AT2S36)/(AKDS36*KT2(I)))-1.)**2)
  510 CONTINUE
      SDA36=SQRT(SUMA36/35.)
      SDB36=SQRT(SUMB36/35.)
      SDC36=SQRT(SUMC36/35.)
      SDD36=SQRT(SUMD36/35.)
c
c
      AKAS18=KAS/18.
      AKBS18=KBS/18.
      AKCS18=KCS/18.
      AKDS18=KDS/18.
      AT1S18=KT1S/18.
      AT2S18=KT2S/18.
      SUMA18=0.
      SUMB18=0.
      SUMC18=0.
      SUMD18=0.
      DO 530 I=1,35,2
      SUMA18=SUMA18+(((((KA(I)+KA(I+1))*AT1S18)/
     \(AKAS18*(KT1(I)+KT1(I+1))))-1.)**2)
      SUMB18=SUMB18+(((((KB(I)+KB(I+1))*AT1S18)/
     \(AKBS18*(KT1(I)+KT1(I+1))))-1.)**2)
      SUMC18=SUMC18+(((((KC(I)+KC(I+1))*AT2S18)/
     \(AKCS18*(KT2(I)+KT2(I+1))))-1.)**2)
      SUMD18=SUMD18+(((((KD(I)+KD(I+1))*AT2S18)/
     \(AKDS18*(KT2(I)+KT2(I+1))))-1.)**2)
  530 CONTINUE
      SDA18=SQRT(SUMA18/17.)
      SDB18=SQRT(SUMB18/17.)
      SDC18=SQRT(SUMC18/17.)
      SDD18=SQRT(SUMD18/17.)
c
c
      AKAS12=KAS/12.
      AKBS12=KBS/12.
      AKCS12=KCS/12.
      AKDS12=KDS/12.
      AT1S12=KT1S/12.
      AT2S12=KT2S/12.
      SUMA12=0.
      SUMB12=0.
```

```
      SUMC12=0.
      SUMD12=0.
      DO 540 I=1,34,3
      KXX1=KT1(I)+KT1(I+1)+KT1(I+2)
      KXX2=KT2(I)+KT2(I+1)+KT2(I+2)
      SUMA12=SUMA12+((((KA(I)+KA(I+1)+KA(I+2))/
     \AKAS12*AT1S12/KXX1)-1.)**2)
      SUMB12=SUMB12+((((KB(I)+KB(I+1)+KB(I+2))/
     \AKBS12*AT1S12/KXX1)-1.)**2)
      SUMC12=SUMC12+((((KC(I)+KC(I+1)+KC(I+2))/
     \AKCS12*AT2S12/KXX2)-1.)**2)
      SUMD12=SUMD12+((((KD(I)+KD(I+1)+KD(I+2))/
     \AKDS12*AT2S12/KXX2)-1.)**2)
  540 CONTINUE
      SDA12=SQRT(SUMA12/11.)
      SDB12=SQRT(SUMB12/11.)
      SDC12=SQRT(SUMC12/11.)
      SDD12=SQRT(SUMD12/11.)
C
C
      AKAS9=KAS/9.
      AKBS9=KBS/9.
      AKCS9=KCS/9.
      AKDS9=KDS/9.
      AT1S9=KT1S/9.
      AT2S9=KT2S/9.
      SUMA9=0.
      SUMB9=0.
      SUMC9=0.
      SUMD9=0.
      DO 550 I=1,33,4
      KXX3=KT1(I)+KT1(I+1)+KT1(I+2)+KT1(I+3)
      KXX4=KT2(I)+KT2(I+1)+KT2(I+2)+KT2(I+3)
      SUMA9=SUMA9+((((KA(I)+KA(I+1)+KA(I+2)+KA(I+3))/
     \AKAS9*AT1S9/KXX3)-1.)**2)
      SUMB9=SUMB9+((((KB(I)+KB(I+1)+KB(I+2)+KB(I+3))/
     \AKBS9*AT1S9/KXX3)-1.)**2)
      SUMC9=SUMC9+((((KC(I)+KC(I+1)+KC(I+2)+KC(I+3))/
     \AKCS9*AT2S9/KXX4)-1.)**2)
      SUMD9=SUMD9+((((KD(I)+KD(I+1)+KD(I+2)+KD(I+3))/
     \AKDS9*AT2S9/KXX4)-1.)**2)
  550 CONTINUE
      SDA9=SQRT(SUMA9/8.)
      SDB9=SQRT(SUMB9/8.)
      SDC9=SQRT(SUMC9/8.)
      SDD9=SQRT(SUMD9/8.)
C
C
      AKAS6=KAS/6.
      AKBS6=KBS/6.
      AKCS6=KCS/6.
      AKDS6=KDS/6.
      AT1S6=KT1S/6.
      AT2S6=KT2S/6.
      SUMA6=0.
      SUMB6=0.
      SUMC6=0.
      SUMD6=0.
      DO 560 I=1,31,6
      KXX5=KT1(I)+KT1(I+1)+KT1(I+2)+KT1(I+3)+KT1(I+4)+KT1(I+5)
      KXX6=KT2(I)+KT2(I+1)+KT2(I+2)+KT2(I+3)+KT2(I+4)+KT2(I+5)
      SUMA6=SUMA6+((((KA(I)+KA(I+1)+KA(I+2)+KA(I+3)+KA(I+4)+KA(I+5))/
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     \AKAS6*AT1S6/KXX5)-1.)**2)
      SUMB6=SUMB6+((((KB(I)+KB(I+1)+KB(I+2)+KB(I+3)+KB(I+4)+KB(I+5))/
     \AKBS6*AT1S6/KXX5)-1.)**2)
      SUMC6=SUMC6+((((KC(I)+KC(I+1)+KC(I+2)+KC(I+3)+KC(I+4)+KC(I+5))/
     \AKCS6*AT2S6/KXX6)-1.)**2)
      SUMD6=SUMD6+((((KD(I)+KD(I+1)+KD(I+2)+KD(I+3)+KD(I+4)+KD(I+5))/
     \AKDS6*AT2S6/KXX6)-1.)**2)
  560 CONTINUE
      SDA6=SQRT(SUMA6/5.)
      SDB6=SQRT(SUMB6/5.)
      SDC6=SQRT(SUMC6/5.)
      SDD6=SQRT(SUMD6/5.)
C
C
      AKAS4=KAS/4.
      AKBS4=KBS/4.
      AKCS4=KCS/4.
      AKDS4=KDS/4.
      AT1S4=KT1S/4.
      AT2S4=KT2S/4.
      SUMA4=0.
      SUMB4=0.
      SUMC4=0.
      SUMD4=0.
      DO 570 I=1,28,9
      KXX7=KT1(I)+KT1(I+1)+KT1(I+2)+KT1(I+3)+KT1(I+4)+
     \KT1(I+5)+KT1(I+6)+KT1(I+7)+KT1(I+8)
      KXX8=KT2(I)+KT2(I+1)+KT2(I+2)+KT2(I+3)+KT2(I+4)+
     \KT2(I+5)+KT2(I+6)+KT2(I+7)+KT2(I+8)
      SUMA4=SUMA4+((((KA(I)+KA(I+1)+KA(I+2)+KA(I+3)+KA(I+4)+KA(I+5)+
     \KA(I+6)+KA(I+7)+KA(I+8))/AKAS4*AT1S4/KXX7)-1.)**2)
      SUMB4=SUMB4+((((KB(I)+KB(I+1)+KB(I+2)+KB(I+3)+KB(I+4)+KB(I+5)+
     \KB(I+6)+KB(I+7)+KB(I+8))/AKBS4*AT1S4/KXX7)-1.)**2)
      SUMC4=SUMC4+((((KC(I)+KC(I+1)+KC(I+2)+KC(I+3)+KC(I+4)+KC(I+5)+
     \KC(I+6)+KC(I+7)+KC(I+8))/AKCS4*AT2S4/KXX8)-1.)**2)
      SUMD4=SUMD4+((((KD(I)+KD(I+1)+KD(I+2)+KD(I+3)+KD(I+4)+KD(I+5)+
     \KD(I+6)+KD(I+7)+KD(I+8))/AKDS4*AT2S4/KXX8)-1.)**2)
  570 CONTINUE
      SDA4=SQRT(SUMA4/3.)
      SDB4=SQRT(SUMB4/3.)
      SDC4=SQRT(SUMC4/3.)
      SDD4=SQRT(SUMD4/3.)
C
C*************************  RESULTS  OUTPUT  **********************
C
      WRITE(*,'(A,I3)') ' FOLLOWING RESULTS BASED ON IIC=',IIC
C
      WRITE(*,'(//,A,E11.5,2X,A,E11.5)')'
     \SDA36=',SDA36,'AKAS36=',AKAS36
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDB36=',SDB36,'AKBS36=',AKBS36
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDC36=',SDC36,'AKCS36=',AKCS36
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDD36=',SDD36,'AKDS36=',AKDS36
C
      WRITE(*,'(//,A,E11.5,2X,A,E11.5)')'
     \SDA18=',SDA18,'AKAS18=',AKAS18
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDB18=',SDB18,'AKBS18=',AKBS18
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDC18=',SDC18,'AKCS18=',AKCS18
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDD18=',SDD18,'AKDS18=',AKDS18
C
      WRITE(*,'(//,A,E11.5,2X,A,E11.5)')'
     \SDA12=',SDA12,'AKAS12=',AKAS12
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDB12=',SDB12,'AKBS12=',AKBS12
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      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDC12=',SDC12,'AKCS12=',AKCS12
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDD12=',SDD12,'AKDS12=',AKDS12
C
      WRITE(*,'(//,A,E11.5,2X,A,E11.5)')' SDA9=',SDA9,'AKAS9=',AKAS9
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDB9=',SDB9,'AKBS9=',AKBS9
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDC9=',SDC9,'AKCS9=',AKCS9
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDD9=',SDD9,'AKDS9=',AKDS9
C
      WRITE(*,'(//,A,E11.5,2X,A,E11.5)')' SDA6=',SDA6,'AKAS6=',AKAS6
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDB6=',SDB6,'AKBS6=',AKBS6
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDC6=',SDC6,'AKCS6=',AKCS6
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDD6=',SDD6,'AKDS6=',AKDS6
C
      WRITE(*,'(//,A,E11.5,2X,A,E11.5)')' SDA4=',SDA4,'AKAS4=',AKAS4
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDB4=',SDB4,'AKBS4=',AKBS4
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDC4=',SDC4,'AKCS4=',AKCS4
      WRITE(*,'(A,E11.5,2X,A,E11.5)')' SDD4=',SDD4,'AKDS4=',AKDS4
C
      DO 888 I=1,36
      WRITE(*,777)I,KA(I),I,KB(I),I,KC(I),I,KD(I)
     \,I,KT1(I),I,KT2(I)
  777 FORMAT(1X,'KA(',I2,')=',I4,1X,'KB(',I2,')=',I4,1X,
     \'KC(',I2,')=',I4,1X,'KD(',I2,')=',I4,1X,'KT1(',I2,')=',I4,
     \1X,'KT2(',I2,')=',I4)
  888 CONTINUE
  998 CONTINUE
  999 CLOSE (2)
      STOP
      END
```

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