A COMPARISON OF PROCESSING CONSISTENCY BETWEEN TELEVISION STATION PROCESSORS AND PROFESSIONAL FILM LABORATORIES AS MEASURED BY DENSITY AND COLOR CHARACTERISTICS OF VNF COLOR CONTROL STRIPS

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The variability of photography has, since its beginning, been determined by the experience, preference, attitude and skill of the photographer; the precision of the taking instrument; the sensitivity of the photographic surface; and the integrity of the developing process. It is this final stage of the chain of photographic events which determines the success or failure of an otherwise perfect picture.

This author has long been concerned with unexplained variations in the photographic process and, therefore, has sought, through this study, to better understand the commercial service that is so vital to the image quality of motion picture film. During the assembly of this work, I have come to appreciate and admire the efforts and contributions of the many pioneers who devoted their lives and fortunes to this artistic science. The vast majority of these contributors never lived to witness the influence of the industries they helped to create, but their legacy stands as one of the truly indispensable institutions of our time. The information expressed herein is my contribution to the already existing wealth of knowledge compiled to this date.

The completion of this study would not have been possible without the patience and assistance of a wide range of people. First, I would like to express my sincere appreciation to my thesis adviser, Dr. Walter J. Ward, for guiding me through the long process without major complications. His direction and skills in the statistical analysis and interpretation of data were largely responsible for strength and reliability

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CHAPTER I

INTRODUCTION

For nearly three quarters of a century, motion picture film as a visual recording medium, has greatly enhanced the documentation of historical events, features, and personalities. Motion pictures, for documentary purposes, are as important today as at any other time in history. The universal 35 and 16mm formats, along with the availability of equipment and supplies, has standardized this form of visual recording all over the world. A variety of electronic recording systems have been developed over the last decade and are today considered indispensable by the television industry. Many of these innovations are, in some respects, an alternative to film; but while their potential for immediate application is an attractive feature, the long-term storage limitations and the compatibility with user's presentation facilities makes motion picture film still the best available format for documentary use today.

The quality of motion picture film images has been improved over the years through a number of technological advancements within the industry. The most important of these are: (1) the improvements in optics, cameras, and ancillary equipment to enhance the conditions of film exposure; (2) the materials developed by manufacturers for motion picture film base; (3) the development of new emulsions with a superior response to

selective lighting, color, and exposure; and (4) the continuous improvement of photochemicals and film processing systems.

Additional factors which influence motion picture quality are: competition between film products manufacturers, pressures from the motion picture industry, exposure requirements of the television news media, increasing competition from electronic news gathering techniques,[1] and the potential of the general public film market.

The users of motion picture film stock, unless they are heavy consumers, must look to the professional film laboratory for processing services. Generally, in-house processing of motion picture film is not practical because of the capital outlay for equipment, supplies, and maintenance, along with the required specialized knowledge and processing experience. A few exceptions to this area are some of the major Hollywood motion picture corporations which are self-contained--film corporations engaged in both film production and professional laboratory services, and the majority of television stations.

Motion picture production and television news filming are generally looked upon as the two extremes of professional cinematography. Theatrical motion pictures are carefully planned and filmed under highly controlled lighting conditions in an attempt to achieve the preferred image quality in each scene. In contrast, television news filming is conducted almost exclusively under existing or uncontrolled conditions which may require an increase in film exposure through forced processing or the use of portable interior lighting. Motion picture production and television

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[1]Electronic news gathering technique refers to the use of portable electronic cameras and video tape recorders that are used in the field by television news personnel in the gathering of news stories.

news film making do, however, share a common ground in the making of documentary films.

Documentary film making is a factual and objective style of film production which, in addition to the historical documentary, includes informational, instructional, educational, industrial and promotional films. This list of categories covers the vast majority of motion pictures which are produced all over the world each year. While many of these films are produced by independents, the ever-increasing market for quality documentary film production is steadily finding its way into the ranks of the television industry which has for years been engaged in documentary production for program purposes.

Although documentary filming is done with a variety of film stocks, the standard of news cinematographers has been, for many years, the Ektachrome reversal color film products of the Eastman Kodak Corporation.[2] These products have performed satisfactorily under forced processing and unfavorable lighting conditions and until now have required pre-hardening and neutralizing stages in the processing to control the swelling characteristics of the gelatin emulsion before entering the first developer.

In mid 1975, the Kodak Corporation introduced a new type of film stock with a high-speed pre-hardened emulsion designed specifically for television news filming. The new stocks in this series were designated Video News Film 7239, 7240, and 7250. The advantages of these new, high quality film stocks were: greater flexibility of exposure

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[2]The Ektachrome reversal color film stock is a type of color film that can be viewed through a projector straight from the film processor, is a camera original film, and does not require printing from original negative film.

under poor lighting conditions, lower quality loss through forced processing, superior picture quality in telecine projection, and a decrease in the cost of processing. Conversion from the regular ME-4 to VNF-1 process to accommodate the new film was accomplished by elimination of the pre-hardening and neutralizing stages which reduced the processing time and allowed for greater volume to meet news deadlines (1).

Since its introduction, Video News Film has been widely accepted by both television cinematographers and independent film makers. At the outset, cinematographers relied upon television stations for the VNF-1 processing service but, in light of the growing popularity of this film stock, many of the professional film laboratories also began to offer the VNF-1 process on a regular basis. With the traditional film lab service for VNF-1 available, many film makers abandoned the television station processors and turned to the film lab service.

This shift to the film laboratories was probably elected for two basic reasons. First, the opportunity to conduct the usual film processing with related services was the same as for other traditional professional film stocks. Work printing and other services could be accomplished immediately following the camera original processing. Second, the film maker could enjoy the confidence of the quality processing that is generally associated with the professional film laboratory. This second reason, however, is open to question in that the quality of a processing service is proportional to the consistency of procedure as defined by the film stock manufacturer (see Appendix A). To date, there is no conclusive evidence to show that film laboratory processing services are superior in quality to those of commercial television stations.

If one considers this in the light of economics and geographical convenience, the television processing service could be every bit as reliable as that of the film laboratory and represents a viable alternative for the independent film maker. With this possibility, we might pose the following questions.

Statement of the Problem

What are the relationships between various television station processors and processing quality as measured by density and color characteristics, and what are the relationships between processing quality and consistency of television stations in general, as compared to the processing quality and consistency of professional film laboratories?

Purpose of the Study

The purpose of this study is to establish some general measure of performance and reliability for both television station and professional motion picture laboratory film processing services that will reflect the degree of variation in processing quality between the processors. In addition, it will establish some degree of predictability with relation to processing consistency within each individual processing system. These measures may be used by cinematographers of television and commercial film making as a reference to the relative quality of television station and film laboratory processing services and may function as a base upon which decisions might be made concerning exposure problems and processor selection. The study may also serve television broadcasters and laboratory personnel as an indicator of internal processing

consistency, thereby providing direction for self-analysis and reassessment of quality control standards for processing operations.

Background and Value of the Study

Film processing requires close adherence to systematic procedures which have been carefully designed and tested by the manufacturer. Each processor develops a method of procedure and conducts the operations according to his own established standards. These standards may or may not conform to the manufacturer's recommendations. If processing conditions are allowed to drift away from the manufacturer's specifications, a steady degradation in quality will follow with less than desirable results.

In the processing of motion picture film, a number of variables have a distinct effect upon the finished product. While each stage of the process can provide its own individual contribution to the overall image quality, the primary influences that determine the final results are:

1. the temperature of the developer,
2. the degree of agitation during the developing stage,
3. the activity of the developer, and
4. the speed at which the processor draws the film through the various stages of processing.

There are a number of operational practices, particularly on the part of some television station personnel, which also influence the quality of processed film. Cameramen sometimes overexpose their film in order to give additional brightness to the television image, or to allow for exposure error when working without a light meter. Occasionally, processor operators will adjust the temperature of the first

developer as a means of image enhancement. Quite frequently, intentionally underexposed film will be force-processed up to three f-stops, which involves temperature changes and/or processor speed alteration (2). This can cause residual differences in subsequent film loads if conditions have not properly stabilized. There is evidence to indicate that proper exposure of newsfilm is, in many cases, of minor concern due to the automatic signal control feature of the telecine.[3]

Some processor operators lower the replenishing rates of the chemicals in an attempt to reduce operating costs. This practice, along with chemical contamination by foreign matter and tank-to-tank chemical transfer, is likely to produce images of variable density and noticeable changes in color characteristics. In addition to variable water quality and microbiological growth, a myriad of chemically unrelated conditions generated by slipshod maintenance procedures can result in dirt, debris, scratches, and blemishes that can permanently damage both the film emulsion and base surfaces (3).

Television stations' processors, being less sophisticated than the film laboratories and usually having only one basic kind of film to process, feel confident in following the procedures outlined by the film manufacturer. They have no trained chemists to conduct daily analyses and, thus, proceed along established tried and true methods, with or without adequate densitometric controls. Film labs, on the other hand, monitor their process in a more knowledgeable manner. Manufacturer's

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[3] In the late 1950's, a self-adjusting video amplifier was developed for video cameras used in converting film images to video images (television). This system was designed to compensate for grossly over and under exposed newsfilm.

standards serve as a guideline and intentional departure from these standards is likely to occur. The motivation for these alternative procedures are varied. The primary reason is probably economic. If the cost of processing can be reduced by using slightly higher temperatures, shorter washes or reduced replenishment rates, an adjustment might be made so long as it is not noticeably reflected in the photographic product. Frequent sensitometric checks are conducted and as long as the process maintains control within acceptable limits, the processing chemistry might be adjusted at will. Another reason for adjusting processing chemistry may be environmental. Should local sewage codes apply pressure to normal processing effluent dumping practices, a cutback on replenishment or some other adjustment is likely to follow. Local water quality can also prompt changes in processing practices that can influence the final photographic process (4).

Variation in procedures, processing time, chemical integrity, and individual preferences and practices may, in addition, vary from one film processor to another, making any form of common processing consistency a condition of questionable reliability.

One major film laboratory conducted workshops in which the company lab services were presented to workshop participants. One of the demonstrations included film samples that were acquired from a wide variety of professional film laboratories. To collect these samples, a quantity of film was exposed in a camera. The subject of exposure was carefully chosen to visually reflect processing differences. The exposed film was then cut into lengths and sent to the various labs for processing. When the processed films were returned, they were spliced together and projected in the demonstration to show the different processing

results from an identical exposure of the same film stock. Unfortunately, there was no quantitative analysis made of the samples used and no written or published record was made of the processing comparisons (5).

Without some measure of confidence in processing consistency, cameramen are forced to rely on chance results once they deliver their film to the processor. Moreover, the cinematographer, whether independent or television station employed, may be at a loss to explain the variation in his exposures if the problem is centered among the processing variables.

The as yet undefined relationships between television station and professional film laboratory processing practices and the density and color characteristics of their processed film represents an informational void in the state of the art of film processing.

The author believes, through numerous experiences and consultations, that there is probable cause to suspect wide variation in the quality of processing on the part of both television stations and film laboratories and that local television station processing services are equally as dependable as those of the traditional motion picture laboratory, in terms of the density and color characteristics of processed film.

This chapter has attempted to introduce the potential for irregularities in the commercial processing of video news film by television station and film laboratory processing operations. The following chapter will trace the development of photography and motion pictures and the subsequent development of processing systems. The application of film to television, along with contemporary processing and control practices, will also be presented.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Throughout the entire history of photography, an effort has been made by the "purists" to develop, maintain, and improve the quality of the product and the process. Photography is a field which has, since its beginning, been equally divided as an art and a science. While the photographer, as an artist, continually strives for perfection in capturing the image, he--as a scientist--is equally concerned with the chemical treatment and stock quality which ultimately determines the physical finished product.

More than a century of photographic technology has had a profound effect upon the character of modern day society. In this long process of development, two related industries have emerged to become recognized as among the most socially dynamic and influential forces of our time. They are, specifically, the motion picture and television industries.

While the artistic rendering of their messages has been the source of their influence, it has been greatly enhanced by the quality of picture image, which is made possible through the efforts of equipment and film manufacturers. Considerable experimentation and developmental research has been conducted by these photographic product manufacturers

and producers of supplies and equipment for photographic application, but as yet there is little evidence to demonstrate the comparative quality and consistency resulting from the commercial chemical processing of a common photographic product.

In view of this absence of research appropriate to the direction of this study, the author elected to include a selected collection of documented events and developments which have made a contribution to the present posture of the photographic, motion picture, and television news-filming industries.

Photographic Development: The Early Years

As early as the sixteenth century, the inverted image phenomenon, later to be known as the camera obscura, was in practical use as an aid in drawing. The principle involved a darkened room with a small hole in the wall. Light, reflecting from an object outside the room, would enter the hole (in very small amounts) and appear as an inverted image on the wall opposite the hole. As the hole was decreased in size, the clarity of the image was sharpened but the brightness of the image was, in turn, reduced in proportion to the restriction. As time progressed, various types of lenses were experimentally positioned in the hole in an effort to improve the brilliance and sharpness of the image.

A considerable refinement of this principle was introduced in the eighteenth century in the form of a portable reflex camera obscura. This device comprised a darkened box with an objective lens mounted in the front to gather light. A mirror, placed inside the box and fixed at a 45 degree angle, reflected the light (image) to a piece of ground glass at the top of the box. This produced an image from which an artist

could trace the proportions of a scene, quickly and conveniently. This was, at the time, the only practical use for the device except for its novelty.

The first evidence of an effort to capture the images of the camera obscura principle came from Thomas Wedgewood (1775-1805) when he attempted directly to superimpose leaves, wings of insects, and various other patterns, directly on paper sensitized with silver nitrate. He also obtained silhouettes by casting a shadow against the sensitized surface but, when viewed in the light, the images created by the light blocking technique began to darken until the image disappeared altogether (6).

Joseph Nicephore Niepce (1765-1833) took the technique one step further and after securing images on sensitized paper, used nitric acid to "fix" the image so it could be viewed in the daylight. However, the technique was only partially successful in that the images faded after a short time (6).

Niepce, however, did successfully develop a related photographic technique. A thin layer of light sensitive asphalt called Bitumen of Judea was spread over a glass plate. With an engraving superimposed over the plate, it was exposed to light for several hours. The areas of asphalt coating exposed to light hardened while the covered areas remained soluble. When the soluble areas were washed away with a solvent, the result was technically what amounted to the first successful photoengraving process.

In the 1820's, Niepce, using a camera obscura, exposed a sensitized pewter plate for an eight-hour period. The experiment was successful and is recognized as the first "picture" taken with a camera. Niepce

referred to his pictures as "heliographs." Since these pictures were, in fact, photo-engraved plates, they could be reproduced by a conventional printing technique.

A few years before his death, Niepce formed a partnership with another Frenchman, Louis Jacques Mande Daguerre, who would carry on his experiments and make a profound contribution to the development of photography.

Working alone, Daguerre perfected the method of sensitizing silver plates using iodine fumes. A plate coated with silver on one side was placed, silver side down, over a box containing iodine particles. The iodine was heated to produce the fumes, and the plate was sensitized by the chemical formation of a silver iodide compound.

In 1835, Daguerre discovered the technique of "developing" the unseen or latent image on an exposed plate by subjecting the exposed surface to mercury vapor. The "developed" image was then fixed with a compound of sodium chloride or common salt. This developing process was dangerous in that overexposure to the mercury frequently resulted in mercury poisoning.

Daguerre had hoped to sell the closely-guarded secrets of his process to one of the various European governments for a handsome profit; but on March 3, 1839, Daguerre's business establishment, along with his entire laboratory containing most of his pioneer work, burned to the ground and, in a state of financial loss, he was forced to settle with the French government for 400 francs ($800) in exchange for the rights to his process. The French government requested that he undertake an effort to describe, in detail, his process so that it could be shared with the French public (6). In compliance, Daguerre

published a handbook outlining each step of his operation, but Frenchmen complained that the handbook was too scientific for the layman to understand. Daguerre was eventually asked to give public demonstrations on a weekly basis to more clearly describe the process.

An American reporter was present at a demonstration held at the Grand Hotel on the Quai d'Orsay on September 17, 1839, and wrote this account of Daguerre himself conducting the demonstration.

> He took a plate of copper plated with silver, and rubbed the silver surface in a slight manner with very fine pumice powder and sweet oil, using small balls of cotton wool for this purpose. He thus completely dulled the surface, and I noticed that he rubbed first with a circular motion, and then with straight lines from top to bottom. He then washed the plate thus dulled in a liquid consisting of distilled water, 16 parts; nitric acid, 1 part. He then gave a slight heat to the plate by passing it over the flame of the lamp, the copper side being next to the flame and the silver surface uppermost. He then washed it a second time in dilute nitric acid. The plate was now ready for a coating of iodine. The apartment was darkened and the plate, fixed on a small board, was placed (with the silver part downwards) over an opening the size of the intended picture, in the lid of a box at the bottom of which the iodine was. Halfway down in the box was a slight wooden frame on which a piece of muslin was strained, and through this muslin, as the iodine evaporated, the fumes rose, and were thus equally received upon the silvered surface, thus forming a coating of iodine of silver, having the yellow appearance of brass. A camera obscura was now brought up. Its focus had previously been adjusted by trying the effect of the picture on a bit of ground glass. The plate prepared as above was placed in the camera. The view intended to be taken was the Tuileries, the Quay and the Seine in front of the window where the camera obscura was placed. It was there to remain until the action of the sun's rays on its surface was sufficient. This occupies a period of from five to forty minutes, according to the time of year and state of the weather, and as the director cannot see by the plate how the process goes on, experience alone can tell him how to judge as to the advancement which the action of the light has made. In this instance, the day was dull and the plate remained fifteen minutes in the camera obscura. When it was taken out, it appeared exactly the same as when it was put in and the people looked very blank, I do assure you, at what looked like a failure; but indeed, one could scarcely tell whether or not it had been marked, for the process requires that no light should fall on it before the finishing operations. M. Daguerre took the plate and held it with the silver part downwards, and

> thus held it for half a minute, while three persons peeped upon it and said, 'Nothing has been traced upon it.' He fixed it then, at an angle of 45 degrees in a box at the bottom of which was an earthen pen holding two pounds of mercury. Under the pan was a lamp which heated the mercury to 117 degrees fahrenheit, and as the mercury became hot, its globules arising, combined with the prepared surface of the metal, brought out the picture. In front of the box is a glass spy hole; through which the process is watched and the moment it was completed the plate was taken out and washed with distilled water saturated with common salt or with hyposulphite of soda, heated a degree below the boiling point. This finished it, and the picture thus literally executed by the sun, was handed about. The time occupied by the whole process was 72 minutes, which is much more than I had been led to expect. I never saw anything more perfect. When examined by the naked eye, every object appeared minutely engraved, but when viewed through a magnifying glass, the difference of grain in the separate flags on the Trottoir was visible, and the texture of everything, if I may use the phrase, was easily distinguishable (7, pp. 24-25).

This eyewitness journalistic account of Daguerre's technique amounts to a concise description of the first complete chemical photographic process. But the Daguerreotype was not without its faults. First, the picture was reversed, the tone was somewhat harsh and all pictures had to be carefully posed because of the long exposures. Another problem was that each picture was a one-of-a-kind and could only be duplicated by being rephotographed or copied by hand.

Most of the problems were corrected as the Daguerreotype became popular and refined as a science. The lenses were improved greatly to let in as much as 16 times more light. The sensitivity was improved by subjecting the iodine-sensitized plate to a second sensitizing with Bromine fumes, and once the exposure time was decreased, the reversed image was corrected by placing a prism in front of the lens. Still, even though the Daguerreotype process required long exposure times and delicate handling of the fixed plates, the simplicity of the system and

quality of production made it the standard of a growing photographic industry for the next two decades (7).

About the same time Daguerre was sensitizing silver plates, W. H. Fox Talbot (1800-1877) was experimenting with sensitizing paper. He had succeeded by treating the paper with silver chloride. The images produced by these methods were reversed in that when the paper was exposed to light with a camera obscura, the light areas became dark and dark areas light--in short, a negative image. He also noticed that when he exposed a second piece of sensitized paper to the negative, the result was a normal positive image. This concept of negative-positive photographic relationship was to become the standard photographic practice of most modern-day photography. Talbot had no effective way of fixing the images of his paper photographs. He subjected them to strong solutions of sodium chloride (salt water) which stabilized the images but they would eventually fade. Talbot, however, after some reluctance, adopted a technique from Sir John Herschel (1792-1871), a mathematician/chemist and astronomer who had a great interest in photochemistry. Herschel had succeeded in developing a new acid from which a number of salts could be derived. It was one of these salts, hyposulphite of soda, that Herschel used to perfect an improved method of "fixing" the images of Daguerre's plates. This practice replaced the use of sodium chloride as a fixer. Herschel is given credit for the discovery of the "hypo" used in modern day darkrooms.

In 1841, Talbot patented his process as the Calotype. The great advantage in this technique was that an infinitive number of positives could be produced from a single negative.

Gustave LeGray (1820-1862) took up Talbot's process and successfully developed a technique of producing a relatively high quality negative on paper. By impregnating the paper with wax, he could use a thinner paper and at the same time achieve a high-gloss finish with images of considerable detail for that period.

Hippolyte Bayard (1801-1877) developed a technique for producing a positive image in the camera. Using paper, Bayard prepared a surface of chloride of silver with a two percent solution of chloride of ammonium. The paper was then dried and sensitized in a bath of 10 percent solution of nitrate of silver. The sensitized paper was exposed to light until it became totally black. It was then washed in several changes of water and preserved until a photograph was to be made. When needed, the darkened paper was sensitized with a four percent solution of iodide of potassium. The paper was then exposed in the camera and, where light acted on the sensitized surface, the iodine entered into combination with the silver, forming an image of iodine of silver. The paper then was fixed in a solution of diluted ammonia and the iodide of silver was washed away, producing the positive image (6).

During the 1850's, and as early as 1847, experiments were being conducted with sensitizing, exposing, and processing of glass plates to serve as negatives for photographic reproduction. Two "wet plate" processes emerged during this period as popular techniques for producing glass negatives.

The Collodion process used a gun cotton solution in which a quantity of iodide or bromide had been dissolved. The glass plate was coated with this iodized collodion, as it was called, and left to dry. The plate then was dipped into a solution of silver nitrate. The iodide or bromide

entered into combination with the silver nitrate, producing an iodide or bromide of silver which was retained on the plate by the fibers of the collodion. The operation was done in the dark, by candlelight. The plate was then exposed in the camera.

To develop the image, a solution of protosulphate of iron or pyrogallic acid in water was poured over the plate and the image emerged as metallic silver in fine powder, retained on the plate by the film of collodion. To "fix" the image, the unreduced iodide, or bromide of silver, was dissolved away in a solution of cyanide of potassium or of hyposulphite of soda.

The other technique appearing about the same time was the albumen process. This was introduced by John A. Whipple and involved dissolving three drams of iodide of potassium, 30 grains of bromide of potassium, and 10 grains of chloride of sodium in two ounces of water which, in turn, were added to a mixture of eight ounces of albumen (the white of an egg) and seven ounces of pure liquid honey. The mixture was beaten to a stiff froth, settled, and strained through flannel. The plate was then coated and laid flat until the coating became sticky. The plate was then dried over an alcohol lamp until the coated surface was no longer sticky.

The plate was then sensitized by dipping it into a solution of nitrate of silver and acetic acid in water, while warm, for about one minute. This bath required constant agitation of the plate. Once the plate was removed from the bath, it was washed slightly (if to be used right away), and washed thoroughly if it was to be stored for later use.

After exposure, the plate was developed with a saturated solution of gallic acid, strengthened on occasion, with an alcohol solution and

a small amount of nitrate of silver. A proper exposure developed in a short time, but over- or under-exposures had to be watched carefully. Extended developing of more than two hours often was necessary. Various modifications of this technique were tried, in many cases, improving the results. Eventually, the albumen process gave way to the more successful collodion process (6).

Early wet plates had a unique sensitivity problem in that they were only sensitive to the blue end of the light spectrum. In 1873, Herman Wilhelm Vogel discovered that by using certain dyes in the preparation of the plates, other details could be brought out. Vogel's plates were sensitive to all colors except red; thus, the developing process could be carried out visibly under a red light. These plates were termed orthochromatic. As the plates improved in their sensitivity, they became sensitive to red, as well, and had to be processed in total darkness. This posed no real problem, however, as the development time was fixed for the emulsions and properly exposed plates generally could be depended upon to "behave" as expected during the development process. These later plates, sensitive to all frequencies of visible light, were termed panchromatic (8).

A reversal of the glass plate negative was first introduced by Ezekiel Hawkins in 1847. Using the collodion process, Hawkins successfully produced a photograph on glass, but it was in 1854 that James A. Cutting secured a patent on a technique for making photographic positives on glass. The collodion sensitized plates, once exposed and processed, appeared to the eye as a negative, but could not be used as a negative. They, like the Daguerrian plate, were a one-of-a-kind item. When the plate was coated or covered on the image side with a dark substance, the

negative image was reversed to positive, as seen through the glass. The technique was known as the "collodion positive" but later was termed the Ambrotype, derived from the Greek word signifying "imperishable." The ambrotype image was prone to deterioration by abrasion and coating failure. The cutting method, however, eliminated much of the problem by sealing the backed image with a second piece of glass of the same size.

The "wet plate process," or collodion process, required that the sensitized plates be kept moist during the photographing operation, from sensitizing through processing. Moreover, it required that all the paraphanelia necessary to complete the entire process be on hand at the site of the exposure. This made outside location photography an extremely inconvenient process. This procedural handicap eventually led to continuing efforts to develop and perfect a viable dry plate process. The collodion process had other problems. The slightest breath across the plate during sensitizing was enough to render it blank when developed. A hot streak of air could damage the plate. The plates also were sensitive to heat, dust, rain, and extreme cold. Water used in the processing had to be of a distilled nature. Nevertheless, the collodion process survived to produce thousands of pictures at the hands of many outstanding photographers, including Matthew Brady, who is best remembered for his photographs of the Civil War battles (6).

The difficulties of the popular wet plate process became compounded when the trend turned to making larger negatives. In 1869, Andrew Joseph Russell documented the historic driving of the spike that connected the tracks of the Central Pacific Railroad with the Union Pacific Railroad on a 10 by 13 inch glass plate.

With the increasing sizes of the plates came pictures of majestic scenery. The larger negatives allowed for greater detail in the resulting prints. John K. Hillers traveled with the expedition of Major John Wesley Powell during his exploration of the Grand Canyon. For six years, Hillers photographed spectacular scenes on 11 by 14 inch plates, all prepared and processed on location.

In 1875, photographer William Henry Jackson joined Hayden's survey of the Rocky Mountains with a camera large enough to expose 20 by 24 inch negatives. He recorded 12 of the huge negatives that were, at that time, the largest plates ever used in field photography. However, at about the same time, a German born settler named Bernard Otto Holtermann, and a young photographer, Charles Bayliss, teamed up to produce a negative three and one-half by five feet. To expose the negative, a 10 foot camera was perched atop a 74 foot tower and was equipped with a 100 inch lens.

The coating, sensitizing, exposure, and processing were all carried out inside the camera. In 1816, a showing of this giant negative in San Francisco earned Holtermann a membership in the Photographic Society of the Pacific.

Because of the overwhelming inconveniences required by the wet plate process, a number of experiments were conducted into the development of a viable dry plate technique. The first consideration was to add to the collodion some hygroscopic substance such as honey, sugar, syrup, glycerin, or possibly beer, to cause a delay in drying and, thus, postpone the crystallization of the excess silver nitrate on the surface. In 1864, F. J. Sayce and W. B. Bolton demonstrated how the silver bath could be eliminated by coating the glass plate with collodion mixed with

ammonium, cadmium bromide, and silver nitrate. These plates could be manufactured and stored for later use, thus, freeing the photographer from making his own. These "collodion-bromide" plates were marketed in 1867 by the Liverpool Dry Plate and Photographic Printing Company, but were inferior in performance, requiring three times the exposure of the more common wet plate.

In 1871, a letter, published in the British Journal of Photography, described a dry plate process whereby gelatin was substituted for the traditional collodion. Richard Leach Maddox, author of the letter and the process, told of soaking gelatin in water after which he added cadmium bromide in solution and then silver nitrate. This was essentially the technique of Sayce and Bolton, with the exception of the gelatin. It was later learned that Maddox turned to gelatin instead of collodion, not because he thought it would necessarily be better, but because he could not stand the smell of ether in the hot glass house where he was doing photomicrographic work.

In the next two years, improvements in the process resulted in photographs being successfully made at shutter speeds of 1/25th of a second. This was accomplished by Charles Harper Bennett, using his own technique of allowing the emulsion to ripen for several days, at 90 degrees Farenheit, before washing. This, along with the washing of the emulsion in its own jelly to remove the excess soluble salts, made the high speed commercial dry plate a reality. The on-site preparation and processing facility could be eliminated and the plates could be processed at any reasonable time after exposure. This brought about the birth of photofinishing. The high speed dry plate process also brought about a new and profound direction in photography.

The tripod was no longer indispensable and the camera could be hand-held. It also put the camera into the hands of the public at large, in the form of small units called "detective cameras." The most popular of these was introduced by a dry plate manufacturer named George Eastman. He called his camera the "Kodak." The name was short, pronounceable in any language, distinctive, and easily remembered. The combination of Eastman and Kodak was destined to become a giant in the field of photography (9).

Around 1855, one of the few distinctly American photography techniques of the early days was introduced and was referred to as the "Tintype." This technique was somewhat of a cross between a Daguerreotype and an ambrotype, in that it traditionally was produced on metal (sheet iron, although other materials would work as well), but used a wet collodion emulsion as the sensitized surface. Like the ambrotype that had to be painted black to convert the negative to a positive, the tintype used a transparent emulsion with the dark metal providing the backing. The image was positive due to the darker tone of the base substance. Like the Daguerreotype, each picture was a one-of-a-kind and the image was reversed.

Hamilton L. Smith of Gambier, Ohio, invented this technique and he called his product a "ferrograph." Smith sold his patent rights to his assistant, Peter Neff, who began marketing the technique under the name of "Melainotypes." A Lancaster, Ohio, manufacturer with considerable experience in producing Daguerreotypes, Victor M. Griswald, began producing similar products under the name of "Ferrotype" plates. Photographic journals objected because of the confusion with a completely different photographic process. The confusions and manufacturers' trade names

eventually contributed to the coining of "tintype" which everyone apparently adopted to identify this particular technique.

The tintype became a favorite process of photographers during the Civil War and found its greatest popularity in the taking of soldiers' portraits. It was not unusual for a considerable number of photographers to follow the armies from battle to battle, to generate business from survivors for portrait sittings. The photos sold for a dollar and more (an enormous profit for the photographer) and were handy for the mail because they were lighter than the Daguerreotypes and held up better than glass or paper in mail handling. The exposure time for a tintype was about the same as for an ambrotype (from 6 to 10 seconds) in that they were basically the same thing photographically. A technical manual on photography, called The Silver Sunbeam, was written explicitly by Dr. John Towler of Hobart College. In his manual, he describes the proper technique for "taking" a tintype photograph.

> Place the cap on the lens; let the eye of the sitter be directed to a given point. Withdraw the ground glass slide; insert the plate holder; raise or remove its slide. Attention! One, Two, Three, Four, Five, Six (Slowly and deliberately pronounced in as many seconds, either aloud or in spirit). Cover the lens. Down with the slide gently, but with firmness. Withdraw the plate holder and yourself into the darkroom and shut the door (10, pp. 165-166).

Not closing the door completely was an apparent mistake made by a number of amateur photographers of the period.

Still Photography and Its Application to Motion

In the 1850's, experimentation and dual lens camera development brought a new trend in photography: the card stereograph. This concept involved photographing an object twice from a slightly different position. When viewed through a device containing two individual eyepieces

properly aligned, the image would appear in three dimension. An adaptation of this device brought about the first crude motion picture invention called the Kinematoscope.

On February 5, 1861, Coleman Sellers, professor of mechanics at the Franklin Institute School, patented the Kinematoscope. Sellers, a mechanical engineer, was also an avid amateur photographer. With understanding of mechanics, as well as photography, he set to devising a machine that could use a series of still pictures and give an illusion of motion. Sellers made stereoscopic pictures of his two sons to demonstrate the action. Through a series of carefully posed timed exposures, he produced several pictures that made a complete cycle of one child hammering on a board while the other child moved back and forth in a rocking chair beside him.

He then placed the flat pictures in a series on a paddle wheel mounted inside a drum. The paddles, mounted on a central shaft, were turned with a knob, flashing the pictures before a tunnel-shaped viewer. The momentary glimpse of one picture, followed by another, made the pictures appear to move, with one boy hammering and the other rocking. While this primitive invention was by no means a true motion picture device, it did establish a principle basic to the mechanics of motion pictures--that of the intermittent movement.

On February 5, 1870, the first simple motion picture projector was demonstrated publicly in Philadelphia, Pennsylvania. Henry Heyl invented the device, which he called the Phasematrope, on the principle that light could be pushed through a transparent substance upon which an image was placed. The light, when pushed through a refracting lens and focused, would show the image on the wall surface. Heyl built his

projection device around a conventional mercury oil lantern, with a wheel supporting the images mounted between the lantern and an adjustable lens. Years later, in 1898, in an effort to call attention to his premier demonstration of motion pictures, Heyl wrote a letter to the Journal of the Franklin Institute describing the device in detail:

> At that day, flexible films were not known in photography, nor had the art of rapid succession picture-making been developed; therefore, it was necessary to limit the views of subjects to those that could be taken by time exposure upon wet plates, which photos were afterwards reproduced as positives on very thin glass plates, in order that they might be light in weight. The waltzing figures, taken in six positions, corresponding to the six steps to complete a turn, were duplicated as often as necessary to fill eighteen picture-spaces of the instrument which was used in connection with a lantern to project the images upon the screen. The pictures on the skeletal wheel were placed in such relative position, that as the wheel was intermittently revolved, each picture would register exactly with the position just left by the preceeding one. A shutter was then a necessary part of the apparatus to cut off the light rays during the time the pictures were changing places. This was accomplished by a vibrating shutter placed back of the picture wheel, that was operated by the same drawbar that moved the wheel, only the shutter movement was so timed that it moved first and covered the picture before the latter moved and completed the movement after the next picture was in place. This movement reduced, to a great extent, the flickering and gave a very natural and life-like representation of moving figures (6, pp. 203-204).

In 1872, a wager of $25,000 was the initial driving force that prompted another significant advancement in the photographic industry and would prove to be of particular application to the development of motion pictures. The wager was made by Leland Stanford, the former governor of California and then president of the Union Pacific Railroad. Stanford contended that a trotting horse, at one point in its stride, lifted all four feet off the ground at the same time. The problem was in demonstrating proof of the action. Stanford hired a photographer, named Edward Muybridge, to take a series of rapid sequence photographs to prove

his point. While Stanford was apparently satisfied that his point was validated by the pictures, the degree of emulsion sensitivity at that time probably left some doubt in the minds of those who viewed the pictures.

Intrigued by the potential of then unknown high-speed photography, Muybridge experimented with different chemical means of accelerating camera plate sensitivity and also made improvements on the shutter mechanism he had developed earlier in 1869. Six years after his original attempt to photograph the stride of the trotter, Muybridge returned to Stanford's farm and began a series of experiments with improved plates and equipment especially purchased for stop-action photography. Twelve Scoville cameras equipped with Dallmeyer lenses and special electrically operated timing mechanisms were installed in special housings on the southside of Stanford's training track. So confident was Muybridge of the experiment, that the press was invited to view the event.

On June 15, 1878, Stanford's horse, Abe Edgington, trotting at a gait of 40 feet per second, passed in front of the 12 cameras, tripping each shutter mechanism by a thin thread stretched across the track. A white background, installed across the track opposite the bank of cameras, upon which vertical lines (21 inches apart) were painted, enabled scientific analysis of the motion, picture-by-picture. Because of the camera arrangement, a rapid sequencing of the 12 pictures made it appear as though the camera was moving with the horse, capturing the animal in a direct profile of stride.

The experiment provided conclusive evidence that a trotter at full speed does, at one time in its stride, have all four feet off the ground. This settled the argument once and for all but, more important, the

demonstration led to development, by Muybridge, of a crude motion picture projector device which he called a Zoopraxiscope.

Not unlike the Phasematrope, Muybridge's device used a rotating wheel to hold the images but Muybridge's wheel was a glass disc with an artistic rendition of the 12 pictures of Stanford's trotter painted around the outside periphery. Instead of the shutter device used in the phasematrope, Muybridge used a second rotating wheel containing slots identically matching the images on the glass disc. The two discs rotated in opposite directions with the image and slot coming into alignment between a lantern and a lens. At this junction, the images were flashed in rapid succession on the screen with the sequential pictures giving a moving portrayal of a horse in motion. While Muybridge had developed a technique of synthesizing actual visually recorded motion, the complexity of performing such a practice with multiple cameras made the technique and the Zoopraxiscope somewhat impractical as a motion picture device. This technique, however, was used extensively for the study of motion where the movement involved a cycle of activity that was conducive to rapid sequence photography from a static multiple camera position (6).

In the early 1880's, a Frenchman, Louis A. Augustine Le Prince, secured an American patent for a motion picture machine that would both expose film and project the images. Le Prince's first machine had 16 lenses which recorded images alternately on two bands of film made from sensitized gelatin. The eight lenses on one side would expose the film in rapid succession, after which the second eight lenses would continue the action to complete the cycle in one second. While one bank of lenses went through its rapid sequence action, the film would be advanced on the other side in preparation for the next cycle. Problems arose,

however, when the camera was converted to a projector. Heat from the arc lamp lighting attachment would warp the film and throw the image out of focus.

In January, 1888, Le Prince obtained a patent for a single lens camera in which images could be secured on a role of sensitized paper. While paper film was unsatisfactory for projection, because it tore easily and did not readily pass light, Le Prince still managed to make a successful motion picture.

A year later, Le Prince acquired a supply of transparent celluloid film in sheets cut and joined to make a roll of film for experimentation; but, before experiments were conducted, he disappeared while on a train headed for Paris and was never heard from again.

An advancement in film manufacture and of critical importance to Le Prince's camera, as well as all motion picture cameras to follow, was the introduction of flexible roll film. In 1885, a company founded by George Eastman announced availability of a box attachment for standard view cameras that featured a roll film mechanism upon which 12 or 24 exposures could be taken. This would replace the single dry plate.

The roll film comprised a gelatin emulsion coated on photographic paper and was probably the film used by Le Prince in his motion picture camera. The paper negatives were made translucent by an oiling procedure, after which prints could be made by the usual darkroom chemical process. Eastman's "negative paper" had one serious drawback. The graininess of the film's paper would be transferred to the prints, interfering with image quality. This grain transfer problem prompted Eastman to introduce a film from which the paper backing could be

stripped away, making the negative transparent and free from graininess; however, the technique had to be conducted with extreme care (6).

The procedure was as follows: After exposure, the film was removed, cut into individual negatives, and each processed. After processing and fixing, the paper bearing the image was pressed face down on a glass plate coated with a solution for removing the gelatin film. Once firmly pressed on the plate, hot water was applied to the film's paper backing which melted and dissolved the layer of soluble gelatin. The paper was then stripped off, leaving the insoluble gelatin film with the image remaining on the glass. Another thin sheet of fresh gelatin was moistened and laid over the image bearing film. The two layers were then pressed together and left to dry. When dry, the two banded gelatin layers were removed and mounted in a printing frame for making prints (10). The delicate handling required during processing of paper-backed film brought about a new and profound service in the photographic industry. Eastman introduced a central film processing service whereby the customer would expose his own film and mail it in, camera and all, for developing. This conjoined with the introduction of the first Kodak camera in 1889.

This camera took circular pictures, two and one-half inches in diameter on the paper-backed (stripping) film with a capacity of about 100 exposures (6). Initial cost of the camera, loaded and ready to go, was $25. When all the exposures were made, the customer simply mailed the camera to Eastman's company where pictures were processed and the camera reloaded and mailed back, all for $10.00. Eastman's slogan was "you press the button; we do the rest." The inexpensive camera and processing

service began a proliferation of amateur photography that spread across the nation (8).

By October of 1889, Eastman's processing service was handling between 6,000 and 7,000 negatives a day. With such a large volume, there was an expected widespread error attributed to mistakes made by the amateur photographers but surprisingly few problems were encountered due to camera mechanisms or defective film. Eastman's slogan succeeded from the start but, in time, the need to mail the camera to the company became a handicap. It would have been much better if the customer could have taken his camera to a local dealer for developing, but the stripping process was too complicated and unprofitable for local dealers. This problem prompted Eastman to search for a base material that did not require a paper backing. His criterion was to develop a material with properties of glass but without its rigidity and fragility. Celluloid already had been used but, at the time, no way was known to produce it thin enough or long enough for roll film.

Eastman experimented with mixtures of cellulose nitrate, grain alcohol, and ether, but the products were far too thin. He tried using successive coatings of collodion and rubber, but still the film was too thin to be practical. He then tried sheets of gelatin backed with varnish in an attempt to overcome a slow-drying problem. A young assistant assigned to this job, experimenting with a varnish of wood alcohol and soluble cotton, found that the combination formed a thick transparent mixture which proved to be the solution to the problem. This, then, was the birth of Eastman's nitrocellulose film support which would eventually dominate the professional motion picture film market.

Plate glass tables, 100 feet long, were assembled and a spreader was devised. In August, 1887, the first practical long film rolls were put into production. In later years, Eastman recounted the discovery of the new base and in a letter to F. H. Richardson of Motion Picture World he said of his present process of film manufacture:

> The support, instead of being made on glass tables as at first, is now cast on the surface of great nickel plated wheels which run continuously night and day, week in and week out. One of these wheels of which we have upwards of 50, produces 25 times as much as the whole of our first factory. The base is turned over to the sensitizing department in rolls 41 inches wide and 2,000 feet long and is so accurately made that it does not vary over one four thousandth of an inch in thickness. Of course, only a part of this product is for motion pictures (11, pp. 29-30).

The letter was written to Mr. Richardson on March 18, 1925 (11).

Eastman was not the first to experiment with a flexible transparent base for photographic purposes. Celluloid was developed in England in 1861. It was not considered for photographic application until a quarter century later. In 1884, a photographer, John Carbutt, persuaded John Wesley Hyatt, proprietor of the Celluloid Manufacturing Company, to produce celluloid in thin sheets. In 1888, Hyatt came through with a sheet of celluloid .01 inches thick which Carbutt promptly adapted to his cameras to replace the old glass plates. While it was not utilized in the same fashion as Eastman's roll film, it was the same basic material with the same basic purpose of exposing film in a camera. It was light, transparent, durable, and almost entirely unaffected by acids or alkalies, remaining unchanged under ordinary atmospheric conditions. It seemingly was a natural substance for quality transparent negatives.

This same substance caught the attention of the Rev. Hannibal Goodwin who also had been looking for a substitute for glass negatives.

Goodwin had experimented with illustrative materials which he used in lantern slide lectures to young people of his parrish. When manufactured visuals became hard to acquire, Goodwin turned to photography for new material. In 1887, he applied for a patent on a method to make photographic film of nitrocellulose. During the next two years, Goodwin's patent was revised seven times.

The commercial potential of celluloid film quickly was recognized by many. An Eastman competitor, the Blair Camera Company of Boston, became a supplier of rollable celluloid film, principally for cameras already on the market and those soon to be introduced. In 1902, T. H. Blair gave a description of his company's manufacturing process:

> The film base (taking the place of negative glass) was formed by spreading the liquid nitrocellulose material on an endless moving surface, as for example a cylinder, where it was given sufficient time to harden to the point where it could be handled without injury by machinery. The film was then stripped from its supporting surface and placed in motion over rollers, allowing air to pass over both sides of the film until it was further 'seasoned'. The film was then transported to a coating machine in a nonactinic department where the sensitive emulsion was applied. Once again, the film was transported on devices which allowed drying and exposure to air to both the newly coated surface and undersurface of the film (6, p. 324).

While importance of transparent emulsion support was evident for the amateur film market, its development was timely for yet another direction in the photographic industry (6).

Motion Pictures: A New Dimension in Photography

As early as 1887, Thomas A. Edison believed it was possible to devise an instrument that could do for the eye what his phonograph had done for the ear, and that the two should be combined to be seen and

heard simultaneously. In 1889, Edison and his wife left for Paris to attend the World's Fair, but not before he had drawn up specifications for a motion picture camera/projector and left them in the hands of his able assistant, William K. L. Dickson.

While in Paris, Edison witnessed a motion picture shown by the pioneer French experimenter, Dr. Jules Marey. Marey shared technical information with Edison on the camera which he used and the "veiwing box" used with the camera; but when Edison returned home, his assistant, Dickson, greeted him with a projected film/sound sequence of Dickson himself, bowing and welcoming Edison home with completely synchronized sound to the lip movement. This motion picture device, when used as a camera, could start, run, and stop a sensitized film at the rate of 46 frames per second. When used as a projector, a lantern was adapted as the light source and an interrupter (shutter) cut off light while each frame was advanced. The entire piece of 35mm film was 50 feet in length, contained 900 frames, and had a running time of less than half a minute.

Moving pictures and sound were together from the beginning. The first motion picture/sound system was mechanically and electrically synchronized together, however, this would not be the case as movie systems became more sophisticated.

Edison's kinetograph, as he called it, functioned as a camera to expose film. When the moving pictures were made, one of Edison's phonographs recorded the sound of the action. The film from the kinetograph was then developed as a negative and a contact positive was made on another strip of sensitized film. After processing, it was ready to be projected by a similar mechanism called a kinetoscope (6).

Edison's motion picture/phonograph system was given the comprehensive name of the kinetophonograph. Used as a recording/exposing system, it was called a phono-kinetograph. When applied as a projection/sound system, it was called a phono-kinetoscope.

Synchronization of picture and sound was achieved by perforations in the edge of the film. The same holes used to register the film in the film gate were used mechanically to govern the speed of the phonograph's rotating drum. Both machines were driven by a common electric motor. Problems of synchronization were simple, in that both picture and sound were contained in one convenient package (12) (13).

In 1891, Edison patented his commercial kinetoscope--a large floor-standing box containing a kinetoscope mechanism and a 50 foot roll of film strung on rollers and spliced head to tail in a closed loop. The device amounted to a peep show, exposing the film to only one viewer at a time. With success of this invention, Edison, in 1893, built a special tar paper hut which was somehow given the name "The Black Maria." Provisions were made to open the roof in sections to let in sunlight. The entire building could be rotated for sun angle. The Black Maria, because of its unique design, became the first exclusive movie producing studio.

Under Edison's direction, a vast number of animal, boxing, circus, and other acts (including Annie Oakley and Buffalo Bill) were "filmed" for showings in kinetoscope peep show parlors which opened on Broadway in 1894. Participants in these films were probably the first professional movie actors. These productions eventually led to the institution called "The Nickelodian" and other nickel theaters (6).

Edison's later kinetoscopes took advantage of another optical principle popular among still photographers. Later models of the

kinetograph were equipped to film and project two images at a time from slightly different points of view; thus, projecting a motion picture stereoscopically or in three dimension (12). Edison failed to patent the kinetoscope or kinetograph in England or France and it quickly was copied and improved, particularly to correct its film breaking tendencies.

It may be said that the motion picture industry began in New York City in 1896 when a machine owned by Edison was used to project a film of vaudeville acts at the Koster and Bial Music Hall. The machine used at this event was called the "Vitascope," however, it was not of Edison's design.

Credit for the invention of the Vitascope was given to a man named Charles Francis Jenkins, who originally became interested in photography in 1890, particularly in reproducing motion. By 1894, he had already developed and demonstrated a motion picture device he called the "Phantoscope." Jenkins eventually lost patent rights to a business partner, Thomas Armat, who also claimed credit for the Phantoscope and other associated devices. Edison acquired rights to the Phantoscope from Armat and re-named the device the "Vitascope."

This device had two features the old Kinetograph lacked. Both are incorporated into motion picture cameras and projectors today. The first was the loop of slack film. This allowed flexibility while the film was pulled down in the film gate and, thus, reduced the tendency of breakage. Secondly, there was a longer period of rest for each picture to be projected. This was made possible by a quicker exchange of frames at the gate.

Another device credited to Jenkins was a film perforator designed to handle longer lengths of motion picture film. Jenkins sold the device to George Eastman for train fare home.

With the Vitascope, Edison found himself again in competition with another motion picture mechanism called the Biograph. Invented by his former assistant, W. K. L. Dickson, the Biograph was said to project larger and clearer pictures than Edison's Vitascope. The Biograph eventually became the only projector used in New York theaters. Edison began legal action against the American Mutoscope and Biograph company and started a series of court litigations that would retard serious development of motion pictures well into the twentieth century (6).

Meanwhile, professional and amateur photography was in high gear. New techniques and processes were continually being introduced.

In an 1895 response to demand for high output printing services, the Automatic Photograph Company, New York, installed a rapid printing and processing operation using high sensitivity bromide paper in long rolls. The system could, in a 10-hour day, produce 147,000 prints with only two workmen. Bromide paper was fed from a supply roll at one end under a half-round, barrel-shaped chamber where exposures were made. Light, to expose the negatives to the paper, came from light bulbs for the required period. Paper then was moved along for the next set of exposures. The long-roll, pre-exposed bromide paper was wound onto a take-up roll for processing. Mass processing was accomplished by loading the pre-exposed roll of paper on a support at one end of a series of chemical tanks, each equipped with rollers to support the paper, and vats or sprayers, strategically placed as processes demanded. Paper was fed into machines in rolls as long as 1,000 yards and three feet wide.

Paper would pass through the various stages at 100 feet per minute and was dried in an enclosed cabinet at the end of the process. Paper then was rolled up on another roller for cutting. While this mass production of photographic prints was designed to handle long rolls for production convenience, it also established a technology that in later years was to become essential in the motion picture industry: the technique of continuous roll processing of long ribbons of motion picture film (6).

Film and Film Processing Development

In 1876, Vero Charles Driffield, a scientist and amateur photographer, and Ferninand Hurter, his friend and colleague, joined forces in an effort to develop a scientific approach to photographic exposure. Driffield had previously stated that "It became intolerable to practice an art which at that time, was so entirely governed by rule-of-thumb, and of which the fundamental principles were so little understood" (9, p. 91).

Their first objective was to develop a technique of measuring the intensity of light. They studied the relationship between exposure or the amount of light falling on a sensitized plate and density, a function which they defined as the amount of silver produced by development. This was done by means of an apparatus made from an old sewing machine and a candle as a standard of illumination. With the candle and apparatus, they exposed plates to successively increasing amounts of light. The silver deposit was measured with a home-made photometer. They then plotted their measurements on a graph.

They found, as they systematically doubled the amount of light with each exposure, that density lagged behind exposure during the first part

of the sequence. It soon reached equality and density increased proportionally with exposure. At the point of exposure saturation, the density variation leveled to a maximum. The resulting plots resembled a line with a concave foot, straight line middle section, and a convex shoulder. This series of plots, they reasoned, was a characteristic exposure range of a given type of emulsion sensitivity and, thus, designated their graphic plots as the characteristic curve.

By plotting characteristic curves, manufacturers were able to test their emulsions. Hurter and Driffield suggested that the sensitivity or "speed" of a photographic plate could be measured geometrically from this characteristic curve.

The opening statement in their report to the Journal of the Society of Chemical Industry for May 31, 1890, summed up the perspective value of their work: "The production of a perfect picture by means of photography is an art; the production of a technically perfect negative is a science" (9, p. 91).

While the work of Hurter and Driffield was fundamental to proper photographic exposure for both still and motion pictures, it was not until 1932 that the practice of chemical processing to a fixed gamma was adopted (11). Furthermore, it was not until the mid-1940's that a universal emulsion speed index was established (14).

Early Film Processing Development

When Thomas Edison requested film stock from the Eastman Company for use in the home Kinetoscope, George Eastman, in a letter, outlined his feelings about nitrate based film:

> Concerning the cellulose acetate film, we are furnishing [you] for your home Kinetoscope, we beg to say that we believe the article to be a perfectly safe one for use in such an apparatus or we would not consent to supply it. In our opinion, the furnishing of cellulose nitrate for such a purpose would be wholly indefensible and reprehensible (11, p. 130).

Eastman manufactured nitrate based film stock until 1949 when the plant was dismantled. At the outset, he recognized dangers of the highly flammable cellulose nitrate in the hands of amateurs. As a result, all film stock manufactured by Eastman for amateur use has been coated on an acetate support.

When W. K. L. Dickson received the film from George Eastman, he must have, at that time, been aware of the need to develop his own printing and processing operation to accompany the motion picture experiments. This was particularly apparent in that Eastman had not yet begun the manufacturing of perforated film for motion picture application. Processing a long ribbon of photographic material was a matter of practice for the mass production of photographic prints and, to some degree, negative film. In that regard, the multiple vat, continuous process technology was available. But space limitations required Dickson once again to turn to ingenuity to accomplish his objectives. He designed and constructed, in crude but efficient form, both a processing operation and a trimming, perforating and printing facility. Because the film was only 50 feet in length, Dickson decided to use black enameled drums to hold the film for the processing operation. The exposed film was wound around the drum, emulsion out, and attached to the drum at each end. The drum then was placed in suspended position with the bottom immersed in a developing solution. The drum was rotated by hand, passing the film through the developer. At each successive processing stage, the drum was

removed from trough to trough, until processing was complete. The film then was dried on the drum by a fan (11).

In 1896, C. Hepworth developed and patented an automatic machine in which film was drawn through a series of troughs for developing, rinsing, fixing, and washing. Later, a perforator and printer were added so the perforating, printing, and processing of a contact print could be accomplished in one operation. In 1907, the Société Des Établissements Gaumont installed several automatic processing machines. Processing solutions were held in tubes; thus, the machines were referred to as "tube" processors. This system originally was developed by H. V. Lawley as an improvement to the Hepworth system.

In 1916, Leon Gaumont secured a patent for a motion picture processor equipped with several tanks in which upper and lower crowned rollers rotated on shafts. This provided a helical travel path for film stock; a principle which is used by modern-day processors.

In 1918, F. B. Thompson devised a processing machine incorporating helical path rollers of varying diameter to accommodate shrinkage of film during drying.

In 1920, the "Spoor-Thompson" processing machine incorporated the friction drive mechanism by applying roller drive pressure to the base side of film, thus, eliminating potential sprocket damage. In the same year, the Erbograph horizontal trough processor was introduced which pulled the film through large pans of solution, stacked one above another. The Erbograph was among the first to employ spray washing (11).

Amateur 16mm Film Development

In 1923, 16mm reversible Cine-Kodak film requiring a controlled

light exposure for re-development was introduced.[1] The technique for development resembled Dickson's processing arrangement by winding the film around a cage type drum for the developing operations. The evolutionary process of 16mm film probably began in 1914 with J. G. Capstaff who was a member of the Eastman Kodak Research Laboratory staff (11). Capstaff witnessed a demonstration of an experimental camera that exposed pictures on half the width of 35mm film at a time. Once the film had been run through the camera, it was removed and run back through in the opposite direction to expose the other half in a fashion similar to early 8mm cameras.

Capstaff borrowed the camera and for the next two years, he experimented with the reversal processing technique which, at that time, was used to develop Lumière Auto Chrome Screen plates.[2] He reasoned that if the camera original could be projected in a positive image it would eliminate need for negative-to-positive printing. This would simplify processing, reduce cost, and open a new dimension in amateur photography.

In 1916, Capstaff demonstrated reversal pictures to Eastman, who was impressed with the picture quality, but reluctant to enter a field with an overwhelming record of failure by other companies. Eastman later approved development of an amateur film but not before re-stating the importance of the safety based acetate film support.

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[1]Reversible film: This pertains to a camera/film design whereby the film is run its entire length through the camera twice, exposing only half the film. The other half is exposed by reloading the exposed roll and running it back through the camera. After processing, the film is split lengthwise and spliced together for projection.

[2]Reversal processing technique: This process involves a controlled re-exposure to light or a chemical developer which acts as a reversing agent, and sensitizes the remaining silver halides in the film producing a positive image instead of a negative image.

A series of trials were made into various picture sizes that would yield an acceptable screen image. The most convenient formula to use would have been to reduce the picture size to one-fourth the standard 1 by 3/4 inch frame, which would reduce the width of the film from 35mm to 17 1/2mm. This practice, exercised by other firms, in nearly every case involved the even division of the dangerous 35mm nitrate based film. However, with the reversal process, it was found and established that a picture one-sixth the normal standard would yield the smallest acceptable image. It would comprise a frame size 10 mm by 7.5mm, allowing 3mm on each side for sprocket holes. The decision to adopt this format established the 16mm standard width of, at that time, amateur motion picture film.

There were four fundamental steps to reversal processing of early black and white 16mm film: (1) a first development to produce a relative image, (2) bleaching of the image with acid-bichromate or acid-permanganate to change the image to a soluble silver salt that could be dissolved, (3) re-exposure to light, and finally (4) a second development of the remaining silver halide to form the positive image.

Capstaff experienced two problems with his early processing. Satisfactory results were attained through only a limited range of original exposures and, secondly, variations in the evenness of emulsion coatings resulted in variations in the final positive image. Capstaff, however, solved these problems for the most part by incorporating a controlled re-exposure of the bleached negative. This controlled exposure later was referred to as "timing" because of the variable length of time given to the second exposure. In short, this practice was a correcting factor for the cameraman's mistakes. If the original exposure was too long

(overexposed), an abundance of silver would be developed by the first developer. This left a lesser amount for the second developing to produce the positive image. An extended exposure before the second developer would preserve a greater amount of silver still remaining in the image, thus, retaining a greater density in the second developer. If the film was underexposed, a shorter re-exposure followed, allowing the second developer to remove excess silver halide to produce an acceptable positive picture. This practice contributed substantially to exposure latitude of film, but the best pictures were realized through proper initial exposure.

The controlled exposure, usually done by a variation of light intensity, also aided in controlling (to some degree) inconsistencies in thickness of emulsion coatings and reduced streakiness and other defects apparent under complete re-exposure.

The controlled re-exposure technique was conducted by a variation of exposures given a test strip. Once processed and dried, the strip could be evaluated in terms of the best results. The film then could be processed and re-exposed according to results of the test strip.

Capstaff modified the first developer solution by adding a silver halide solvent and a hardening agent. The solvent improved the image while the hardening agent prevented reticulation of the gelatin during the various steps of processing.

As the period of development in 16mm film format continued, Capstaff worked closely with the Hawkeye Works to produce a perforator for punching precision sprocket holes in the film. This effort also included a camera and projector to conform to the sprocket frame format. At the

same time, Capstaff worked closely with the film manufacturing department experimenting with various emulsion coatings on acetate base (11). (See Appendix B.)

The film chosen for production was an orthochromatic emulsion on the required acetate base with a black paper leader and trailer for loading and unloading in the daylight. The film was perforated on both sides with rectangular sprocket holes with rounded corners.

In 1923, the 16mm format was introduced to the public as amateur motion picture photography. Because of its simplicity and low cost in comparison to its predecessors, it was quickly accepted by the international community and rapidly spread in popularity.

The new 16mm reversal film process technique, designed to eliminate the negative-to-positive printing requirement for amateur film, reduced the cost to one-sixth that of the previous method. Another advantage of the reversal process was that it was "astonishingly free from graininess." While this was a result of the special film used, it was primarily because of the process itself. In this process, the largest grains and clumps, formed during the first development, are removed by the bleach, leaving the smaller grains to be developed as the positive image.

Early 16mm reversal films were processed with a hand-cranked mechanism comprising a barrel-shaped cage of hard rubber end plates connected by glass rods. The cage, or reel, as it was called, was placed over a trough filled with solution for the developing process. The film was wound spirally on the "reel" and was immersed in the developing solution as the reel was rotated manually. After the process was completed, the

film was wound on a second "reel" located over the first, where it was dried by a small electrically-powered blower (11).

The original camera used by Capstaff in 16mm film experimentation was a hand-cranked device constructed by Harris B. Tuttle, Sr. (15). Tuttle worked closely with Capstaff and was the chief processing engineer during 16mm development. The following descriptions are from his notes on the 16mm reversal development process.

The original hand-cranked reel was wood, impregnated with boiling hot paraffin. This combination was chosen to inhibit absorbtion of alkali developer or acid bleach.

Film was held to the reel with a looped rubber band at each end. The reel was positioned over a vat containing processing solution so that film would be immersed as the reel was rotated. The solutions were emptied from the vat after each step. The vat, used to hold the chemicals, comprised a metal tank lined with heavy toweling and coated with paraffin. Each piece of film was measured on a step tablet before the second exposure was given. A four inch piece was cut from the end and given a 10 second exposure, developed for five minutes, and fixed for two. It was then compared to the step tablet for an over-all second exposure.

As time progressed, an estimate by the eye of the trained lab technician was determined to be sufficient and was much faster than using the step tablet. Light or dark segments within the various properly exposed scenes were compensated for by holding a piece of cardboard up to block the light for the required amount of time (15).

The popularity of 16mm amateur film continued to grow and, because of limited capacity, the "twin reel" machine was abandoned in favor of

a more sophisticated "tube machine." These tubes were used to hold the various chemicals as the film was drawn from tube to tube through the processing cycle.

Manual control of a density step table was used for the second exposure and set by the operator for each scene change. While the tube machine could process hundreds of feet of film in each run, there were problems that quickly made the early tube systems obsolete.

The machine was plagued with mechanical difficulties, glass breakage, and various other design problems due to replenishment, agitation, and temperature. The early tube system eventually gave way to the more compact rack and tank processors.

Until 1928, all reversal film comprised orthochromatic emulsion on an acetate support. The orthochromatic emulsions were convenient for processing personnel because of a characteristic insensitivity to red. The processing operations could be carried out under a photographic red safe light.

In 1928, Kodak introduced its new Cine-Kodak Panchromatic film which was sensitive to all the colors of the spectrum, thus requiring total darkness for all loading and processing. With improved methods of sensitization, Kodak introduced their supersensitive panchromatic film in 1931 and later, in 1938, their Super XX Panchromatic film. Meanwhile, in 1928, Kodak introduced its first rendition of 16mm color film to the amateur market. This mildly successful idea was purchased from the Société Du Film En Colours Keller-Dorian, which was originally an invention of Rudolph Berthon. It was marketed in the United States under the name Kodacolor. This "color" system utilized the traditional Panchromatic black and white 16mm film, having embossed on the base side several

hundred tiny cylindrical lenses extending lengthwise of the film. The camera used for exposing the film was a standard 16mm movie camera with a banded three color filter placed over the lens. The film was loaded with the base side toward the lens and, when in operation, the embossed lenses guided the rays from each of the three filters and impressed these filtered images on the emulsion. The film was developed in the standard reversal process and, upon visual inspection, appeared to be a black and white print (11). When projected in a standard projector, it would appear monochrome on the screen; but if the projector was fitted with a three-banded color filter, the picture would appear in color.

Other early additive color techniques for 16mm film were introduced in the early thirties and were equally limited in their success. AGFA, a German firm, introduced (in 1932) a lenticular film, similar to Kodacolor, called Agfacolor. The technique flourished for only a few years and like Kodacolor, became quickly obsolete.

Another technique, called Dufaycolor, was introduced in 1934. A mosaic screen was produced on the film support and a fast Panchromatic emulsion was coated over the mosaic screen. The screen had a geometrical pattern of blue and green squares, separated by red lines that produced about one million color filter elements per inch. The film was loaded in the camera and exposed with the base side toward the lens. It was processed by reversal and projected a color image.

In 1935, a multi-layer film containing sensitizing dyes was introduced under the name "Kodachrome" (see Appendix C). This subtractive type color film contained no couplers to keep the dyes from wandering, which was a fundamental problem with the monopack color concept. Instead, the couplers were included in the developer solution. The process

was clumsy and complicated, but produced acceptable visual results. The process for developing was as follows:

> After exposure, the film was developed to a negative and the negative image in each of these layers was removed by bleaching with permanganate. The film was then given a fixed exposure to light to make the silver bromide images developable and the whole film was developed to produce a cyan-dye in all three layers. After drying, the film was treated with a bleach of low penetration which removed the dye from the top and middle layers and regenerated the silver bromide which was then developed to form magenta images. The film was dried again and treated with a very low penetration bleach which removed the magenta dye from the top layers and converted the silver to silver bromide so that it could be used to form a yellow dye image. The remaining silver was then changed to silver halide and removed by fixing, leaving the three dye images which formed the positive color image upon projection (11, p. 139).

Professional Film and Processing Development

While 16mm acetate based film was being developed for the amateur market, a continuing parallel effort was under way to improve "professional" film. Edison's 35mm format was still the standard for theatrical motion pictures, but continued to be coated on the highly flammable nitrate support.

In 1927, Kodak introduced a new Borax developer which allowed longer developing times and produced a finer grain product. In the same year, C. R. Hunter, using a modified Spoor-Thompson processor, began the continuous process development of camera original negative film. Up to this point, accepted process handling of professional camera original negatives was conducted under the watchful eye of "expert" laboratory men. They would make adjustments for exposure variation during the processing operations. In 1928, results of a demonstration at Universal City were so favorable that in August of 1932, an announcement was made that three

of the largest Hollywood studios had begun developing all negatives to a fixed gamma, thus limiting the cameraman to methodical exposure procedures.

Research on the variable density characteristics of optical sound tracks applied the sensitometric measurement to arrive at optimum processing conditions. Success experienced with sound tracks was transferred to the processing control of motion picture film negative and prints. This standardized the time and temperatures of the processing operations and determined the standards under which a given type of film should be exposed. These practices allowed laboratory personnel to concentrate on the consistency of conditions within the various steps of film processing and, at the same time, revealed inconsistencies in camera exposure and manufacturing practices (11).

Also, in 1928, the Technicolor Corporation introduced their special two-color imbibition process of dye transfer printing for two-color motion picture prints. The process initially was successful because of its novelty, but it still lacked true color rendition.

In 1931, electrolytic silver recovery units were initiated in many laboratories. Prior to this time, silver was recovered by precipitation as a sulfide in the fixing bath. In 1932, Technicolor modified its cameras to film in three separate colors and the imbibition process also was modified to include the third color for the printing of full color release prints (see Appendix C).

In 1940, chemical replenishment techniques were incorporated into continuous processing systems and attention was turned to turbulation or agitation of processing chemicals. Problems of "directional effects" or "sprocket hole modulation" were attributed to the uneven agitation

action caused by the film's sprocket holes as they moved through the solution. The uneven agitation caused density variation which became pronounced in the music soundtrack. The problem was solved by flowing the developer into the top of the tank and down the vertical moving strands of film.

In 1946, rapid processing was introduced. This system was devised by Paramount Pictures for processing black and white print film from a negative. Instead of processing at 68°F, the temperatures were raised to 120°F. Early experiments achieved a processing cycle of three minutes (11).

In 1950, solution temperatures were raised for the other steps and high velocity air drying was introduced. Cycle time was reduced to only 25 seconds. Demonstration of both the conventional processing (40 minutes) and the high-speed processing (25 seconds) were shown at the 1950 convention of the Society of Motion Picture and Television Engineers. Identical prints, taken from the same negative, were projected and the audience was asked to state which print had the higher quality. Approximately 85 percent voted in favor of the print processed in 25 seconds (16).

A need for 16mm high-speed reversal film processing was expressed by organized horse-racing associations in the 1940's to determine the official winners of each race. The first technique was by rack and tank process which resulted in water spots, staining, and reticulation of the film. With temperature and emulsion limitations, the film, by commercial service, could be delivered in no less than 20 minutes. Through processor modification and utilization of DuPont Type 330 emulsion, time was reduced to five and one-half minutes by 1950. With the introduction of

type 930 film, incorporating a super hardened emulsion, the time was reduced to three minutes.

The Delaware Steeplechase and Race Association commissioned the E.D.L. Company to build a new processor, designated the D.M. II, which was installed at Delaware Park in May, 1954. The processor worked with solution temperatures of 110°F to accomplish a 48-second processing cycle. The length of film added to the processing time constituted the overall time necessary to determine the winner of the race (about two minutes). The development of this high-speed processing system allowed Delaware Park to produce "Spot news" television shorts and present them to stations only minutes after the race was completed (17).

During the mid 1940's, at about the same time the trend for rapid processing began, the American Standards Association established the now existing sensitometric procedure for obtaining a film's characteristic curve. Up until this time each meter and film manufacturer had its own set of ratings for any given type of film stock. The new procedure, based on the experiments of Hurter and Driffield, established a specific emulsion speed rating and is today referred to as the ASA exposure index. This rating is assigned to a given emulsion by the film manufacturer and is the governing factor in the exposure of all still and motion picture film stock (14).

Sixteen Millimeter Film and Its Compatibility to the Television Industry

Experiments in high-speed black and white film processing were timely developments in an era when radio was rapidly being replaced by television as a source of home entertainment and news. It was learned

quickly that television involved more than just putting the announcer on camera. News coverage involved a visual reporting of events at the scene.

It became quite apparent when television news began that the 16mm camera would be used primarily for reasons of economy as well as portability. Newsmen needed something similar to the radio type recorder. Because of time involved in editing and telecasting film, they were forced to use single system sound cameras (18). This universally-adopted news reporting technique brought about a major transition in the film industry. The 16mm format, long recognized as an amateur film stock, was now the standard for television news (both local and network) and was quickly adopted as a professional film format. But, with the blending of television and film, there were problems and concerns.

H. J. Schlasly (19) stated in January of 1951:

> The merger of electronics and photography into the corporate function of television recording is a situation which is logical and natural but which, nevertheless, has caused a number of serious conditions. The problem is simply one wherein two sciences that have been comparatively independent of each other suddenly found that they define and describe certain phenomena in terms which are not identical, but are similar enough to be thoroughly confusing. The ultimate objective of both television and film is the faithful reproduction of an original scene. While the beginning and end products are the same, the medium and methods are widely different.
>
> In general, the deterioration contributed by any physical device is evidenced by a gradual reduction in contrast ratio with increasing detail until a point is reached where there is no distinction between two adjacent points which did have some quality of distinction in the original. Whether this contrast ratio is measured in light energy, grains of silver deposits per area, potential difference or whatever, is immaterial (p. 44).

Otto H. Schade (20), in an article to the SMPTE Journal on Film and T.V., stated:

> The reproduction of images over a motion picture and television process involves a large number of transfer elements. Shape and contrast range of the transfer characteristic of a normal motion picture positive are adjusted to fit the optical conditions in direct screen projection. It is logical, therefore, that the characteristics of motion picture film intended as a picture source for reproduction by a television system or for storage and reproduction of video signals, should be adjusted to fit the range and transfer characteristics of the television system and not the eye (pp. 155-157).

In comparing the television vs. the photographic process, Schade went on to say:

> In practical processes, the optical image is formed on a photosensitive material which releases photoelectrons when it is bombarded by light quanta. This sample conversion process generally reduces the number of samples, but it permits their accumulation and storage. In the television process, the electrical samples can be stored directly as a 'charge image'. In the photographic process, the photoelectrons combine with silver ions in a secondary conversion process to form submicroscopic silver samples (grains) which in turn, can be accumulated and stored as a latent image. Following these processes which take place upon an exposure of a light-sensitive surface, are processes of multiplication or development in which the electron energy or the mass of the silver sample is increased by large factors to become sufficient for the transmission of information and the control of light sources for image reproduction (p. 139).

During the late 1950's and throughout the 1960's, a widespread concern was circulated with reference to quality of film used on television. In the 1957 spring convention of the Society of Motion Pictures and Television Engineers, a paper was presented which opened the eyes of many skeptics of television film quality. The paper dealt with a self-adjusting video amplifier for use with telecine camera chains to compensate for variable densities in the projection of news film. The system was designed to accommodate variations in film transmission of the order of 10:1. When the large compensating factor design was questioned, discussion revealed that investigations at operating points indicated

variations in the lighter areas of film images between 85 and 2 percent. This, translated to a density equivalent, implies a minimum density in the pictures of from .06 to 1.70. With extremes such as these, film was being processed for television that contained highlight areas equal in density level to the shadowed areas for normally projected broadcast standards (21).

At about this same time, supervisors for the English Language Network of the Canadian Broadcasting Corporation estimated that no more than 10 percent of film supplied for telecasting could be classified as first-class quality. They maintained that 40 percent was mediocre and the remaining 50 percent should be rejected (21).

On June 23, 1965, a paper by Woods, Sanders, and Griffiths (22) pointed out a variety of errors in various samples of film and divided them into five categories: (1) excessive general density of the film (underexposure), (2) inadequate general density of the film (overexposure), (3) excessive density in one or two of the three emulsion layers, (4) black crushing in any one or two of the three emulsion layers, and (5) white crushing in any one or two of the three emulsion layers. Related to white crushing is an effect which might be termed "black stretching." The paper further stated that defects 1 and 2 are most likely to be attributed to exposure error, either in the camera or in printing. It also may be a result of the film processing. Other errors may be traced to incorrect filter selection during color compensation in the printing phase. Corrections 1 and 2 can be compensated by master gain controls. Three, four, and five required a compensation by differential adjustment of the contrast laws of the individual color

signal channels. Adjustment should be carried out by means of a subjective appraisal of highlights, skin tones, and color in deep shadows.

In 1970, a trained group from Eastman Kodak Company visited all television stations in the United States and Puerto Rico to evaluate operational procedures of television color film chains. Evaluation consisted of establishing a proper gray scale balance and correct gamma of the telecine camera with the Kodak cross-step gray scale slide; second, evaluating the colorimetry of the television film chain using a film of known good quality and proper color balance by observing it on a color monitor set to D 6500.

Some stations were found to be using excessively low projector lamp voltages to lengthen lamp life. Another common practice was stopping down of the projection lenses to increase the depth of field and eliminate re-focusing when running the reversed emulsion on 16mm films.

Several problems were found to be frequent causes of poor quality of television images from good film. Among them were (1) poor film chain performance and (2) lack of color balance uniformity between chains. The main reason given for conditions of film chains was lack of well-defined parameters for establishing the optimum condition of the color film chain camera (23).

Various set up procedures discovered were (1) wide variation of gray scale test objects, (2) arbitrary use of "favorite" color films which were totally unstandardized, (3) many stations used no reference materials at all, (4) many stations used 2 x 2 test slides to set up the telecine chain (some were not neutral which biased the camera color balance). In general, little consistency surrounded the telecine setup.

The second phase of the study had to do with film preview practices. The group evaluated preview facilities and found all stations were using unmodified tungsten projectors which varied greatly in color temperature from the D 6500 video standard. To be compatible, the projectors needed to be converted from 32-3400K to 5400-K for proper visual evaluation (23).

The survey of telecine systems among television stations found there was no real standardized procedure (from station to station) for initial daily set up of the telecine equipment and electronics. It also was found that practically all 16mm telecines were operated with automatic signal level control to accommodate variable density film which tended to discourage any attempts to improve quality of film reproduction. This survey concluded that the telecine had been contributing significantly to the poor reproduction of film in most stations, which may imply an indirect influence on both exposure and processing quality (24).

While the concern of these surveys and articles were oriented toward film quality on television, the attention centered around the optics and electronics of the telecine (film chain). A study by D. M. Zwick (25), in 1968, investigated various types of film intended for use in the telecine on a broadcast basis. Study results were presented at the SMPTE Conference in Miami Beach on April 22, 1969. A variety of film samples intended for television were volunteered for the study and were divided into seven categories as follows: (1) 35mm for prime time shows; (2) identical prime time shows in 16mm format; (3) overprints (extra prints) of 16mm spot commercials randomly selected; (4) obsolete prints (35mm) of commercials, random selections; (5) 16mm prints of the same commercials; (6) outtakes of 16mm color news film, both network and

local stations; (7) SMPTE reference test films, 16mm and 35mm. The first test was completely visual on a five point scale: (1) excellent; (2) good; (3) probably acceptable, but not very good; (4) poor (not acceptable); and (5) horrible. All samples were viewed at various color temperatures from 3000°K to 6500°K.

During projection, certain areas were selected for densitometric measurement: a white reference (shirt collors, white fabric, etc.), a black reference (hair, dark shadows, etc.), and flesh tones (forehead, cheeks, and neck below the ear). Diffuse densities were measured on an Eastman densitometer, model 31A. A visual neutral filter was used for blacks and whites, and Status A red, green, and blue filters for flesh.

Higher quality film samples exhibited a greater average density in both black and white but no correlation between quality and density on flesh tones. However, SMPTE flesh density and network programming flesh densities peaked at about 0.80, while commercials peaked at about 0.60 flesh density, displaying a marked difference between intercut commercials with program material.

Study conclusions, based on the SMPTE standard and sample density measurements, were that black density measurement of 2.50 $\pm$ .20 should be acceptable and a white density from .25 to .40 can give good quality. Also, a majority of Caucasian flesh densities from 50 to 80 percent of peak white should assure correct flesh tone reproduction.

Network programming samples compared closely with SMPTE test films. News film showed less variation than did commercials. However, the study did not reflect a great deal of information about news film quality (25).

A number of demonstrations and seminars were conducted in an effort to "educate" producers of television commercials on the technical characteristics required for good telecasting. These efforts were held following the 1968 study on color and density balance.

The study was repeated in 1973 to assess any noticeable differences using a new population of film samples. These samples comprised (1) all commercials broadcast by a large television station during a particular time span; (2) a random sampling of commercials supplied by an east coast source; (3) a supply of commercials from the west coast; (4) television news film, network and local both domestic and overseas; (5) entertainment samples, 35mm and 16mm prints (this sample was small and represented only one network) (26).

Evaluation of films was conducted by (1) visual qualitative assessment and (2) density and colorimetric data. The density and colorimetric data were collected through instrumented evaluation of a projected picture and by conventional densitometer. White densities fell between 0.15 and 0.30 with a peak of 0.23.

Sixteen millimeter prints of entertainment programs ranged between 0.20 and 0.35 with a peak of 0.30. Sixteen millimeter film commercials ranged between 0.15 and 0.25 with a peak near 0.20. Sixteen millimeter news film was more dense with a range of 0.25 to 0.45 with a peak close to 0.40. When 16mm news film was compared to 16mm commercials and entertainment films, a marked difference was observed. Commercials and entertainment films had an average over-all density of 0.66, while news film (as a group) peaked at about 1.15.

In all cases of 16mm film, there appeared to be a relationship of higher density white levels with visually acceptable film samples. This,

then, associates "thin" whites with poor picture quality, especially when viewed on a television monitor, according to the study.

Black densities ranged from about 1.70 to 3.00 with a peak of 2.2. Of all 16mm film samples, news film typically had greater density in black areas. It was noted that news film of poorer quality has fewer black densities falling in the 2.10 to 2.40 range.

Study conclusions indicated an over-all improvement in color balance with a reduction in over-all density in the commercial films. While programming film was about the same, news film appeared a little better in color. There was little improvement overall and news film continued to be the coldest of all groups (26).

These studies added significantly to existing knowledge of telecine characteristics, but the aforementioned studies on film addressed only the immediate characteristics of the films tested. Conditions which produced those characteristics were left unexplained. Unexplained variables, in most cases, involved multiple generations of prints which became lost in "timing" for correction of color and density errors. In any case, the most fundamental variable (which went untested) was that of camera original processing.

Contemporary Motion Picture Film Processing and Control

In the early days of television, news film predominantly was processed by an outside service on a daily basis. As the television industry grew, individual stations began to acquire processing machines of their own. This arrangement seemed satisfactory until the big transition from black and white to color television occurred and the stations were forced

into three options: (1) scrap or sell black and white processing machine and purchase a new color processor, (2) turn to an outside film laboratory for processing service, or (3) continue to use black and white film reporting intercut with color studio and network programming. All three options had a wide following but, due to the competitive factor, eventually all network affiliates and most independent television stations converted to color news film.

Because of various conditions under which news film was exposed, selection of film stock by television news cinematographers was nearly universal. The high-speed Ektachrome film stocks manufactured by Eastman Kodak became the standard of the industry and color processing machines were selected and purchased accordingly (27).

While the popularity of in-house color film processing continued to expand, professional film laboratories were extending their processing services to those television stations that did not operate their own facilities. They were, however, at the same time engaged in the processing of a variety of film stocks for regular customers. This, then as now, has required incorporation of several processing machines under the same roof to handle the variety and volume (28). An article by Hedden, Sutton, and Gyori (29), in 1963, described the basic design of a custom film laboratory processor and emphasized the importance of mechanical and chemical safeguards:

> In processing original camera film, losses must be kept at about zero. Original film is almost impossible to retake. The machine, therefore, must be almost fool-proof in its mechanical ability to run film without loss. The color quality and consistency of the product also must be extremely high. Very high standards of processing color quality already have been set up by the film manufacturer and other commercial laboratories offering this service (p. 27).

Processing solutions present a variety of chemical problems such as corrosion, silver deposition, contamination of chemicals, microbiological growths, etc.

> Both Ektachrome commercial and Ektachrome ER films [this film is no longer used] are processed on the same machine. The two processes require different solution developing times. This is accomplished by running the ECD film at 50 feet per minute and the ER at 30 feet per minute. Safeguards include double belts, re-exposure lamps, circuits and relays, to eliminate the chance of machine breakdown due to single failure, etc.; also flowmeters and temperature control mechanisms.
>
> Since more than half the Ektachrome process can be operated in room light, the machine was made in two sections. The dark end accommodates those steps requiring almost complete darkness. In this section, the film is delivered for processing. There is no substitute for an adequately equipped, adequately trained chemical control laboratory. Spectrophotometers, pH meters, and the usual assortment of analytical techniques are required. Sensitometry measures film quality in terms that can be evaluated and plotted for control. Readings are translated to a chart showing continuous operating conditions. Limits of quality tolerance then can be established and variations from these limits minimized (29, p. 31).

In another article, Hedden (30) described one laboratory's technique of processing controls:

> Photographic control is necessary to enable the technician to evaluate process conditions and to provide a means of measuring variability. Sensitometric strips exposed on a special sensitometer are processed along with the film, at definite intervals. A photographic picture strip containing a soundtrack is also processed along with each sensitometric strip. This picture strip is exposed on a production printer and provides a quick double check on sensitometric strips (pp. 574-575).
>
> Process variations appear primarily to be caused by the processor chemistry. By controlling the process chemically, the photographic and mechanical controls serve mainly as checks on the accuracy of the chemical control and physical operation of the developing equipment (p. 573).

A number of observations were made concerning the problems of control of the color photographic process by Allen M. Koerner (31):

> Experience has shown that in those instances where difficulty has been encountered in controlling a process, it has been because of the failure to observe one or more basic principles of control and the failure to recognize the true nature of these processes (p. 225).

Four phases of processing control are: (1) knowledge of the desired characteristics of the process and the product, (2) continuous evaluation of the status of the process to determine whether these characteristics are being maintained, (3) diagnosis and the location of the problems indicated by evaluation, (4) the taking of proper corrective action after trouble is located (see Appendix A).

The film is manufactured and tested. It is then shipped to the customer who exposes it, after which it is processed and returned to the customer for review. There is something very final about this because, once the film comes off the processing machine, there are no additional steps possible to correct an error.

> 'Pictures' are the end and 'chemistry' is the means. If camera original film appears to be off-color, a compensating adjustment of the color of the filters used in the printing operations will afford a degree of correction. However, if it becomes the rule rather than the exception, that the chemistry of the processor is permitted to differ greatly from the manufacturer's process, the results may be unpredictable.
>
> The performance of chemical analysis should be supervised by trained analytical chemists. Poor analyses are worse than none because they breed a degree of unjustified confidence (31, p. 226).

While chemical analyses assure maintenance of a stable process over long periods, the photographic strips give an hour-to-hour assurance that no unsuspected accidents have occurred to move the process away from standard. But sensitometry must be administered with meticulous attention to numerous details if it is to be effective. In applying sensitometry to the evaluation of processes, certain critical assumptions must be made:

a. The sensitometric exposures are identical from strip to strip. The sensitometric exposure must be critically identical. Rigid regulations of the power supply to the exposing light source of the sensitometer is extremely important. Any poor solder joints, or variation in line voltages, can influence the characteristics of the exposing light beam. The mechanism controlling the length of sensitometric exposure must be repeatedly precise. Maintenance of a sensitometer is important and should be checked frequently.

b. The sensitometric strip film stock has been manufactured to uniform specifications throughout its length. Film stock uniformity is reasonably dependable so long as the sensitometric strips are cut from a common batch. Differences can occur from batch to batch; therefore, when conducting sensitometric tests it is important to maintain consistency when processing sensitometric strips. Intermixing strips from different batches to the same reference should be avoided.

c. The unprocessed sensitometric strips are stable with time. Film is not, under ordinary conditions of temperature and humidity, precisely consistent. Aging can change its characteristics. Once it has been exposed in a sensitometer, the latent image changes with time. Manufacturers recommend freezing film before exposure if it is to be stored for a time. If control strips are purchased from the manufacturer, they should be kept frozen until used.

d. The sensitometric exposures are a close approximation in duration and quality of light to those encountered in the actual use of the material. Using different exposures, either timewise or colorwise, can be as serious as using sensitometric control strips of one type of process to measure an entirely different process.

e. The Gray scales, as an abstraction of picture quality, are adequate for processing control. Sensitometric strips usually are exposed to a Gray Scale and, on occasion, include prime color patches as in the manufacturer's standard. In this sense, a sensitometric exposure represents an abstraction of total information available in a given quantity of color film. The extent to which the information is abstracted can be increased or decreased, depending upon how many density steps are included in the Gray Scale wedge.

If the diagnosis and location of trouble is to take place promptly, it is advisable that the data derived from chemical analysis and sensitometric control strips be plotted in the proper time sequence on a control chart. The control charts should show the standard levels as straight horizontal lines around which the actual readings will be plotted. In addition to the standard levels, permissable tolerances also should be shown (1) (31).

Abrupt changes in processing chemistry are rare. Because of the quantity of chemicals in the processors, the changes will be gradual and easily detected through standard daily chemical and sensitometric procedures. Corrections usually can be made before tolerance levels are reached.

The time, temperature, agitation, and purity of the processing chemicals are keys to predictable results. As a rule, in well-controlled processes, some abnormality in chemical levels will be found which will correlate with an off-standard densitometric reading. The characteristics of densitometric plots, along with chemistry analyses, can pinpoint specific processing problems.

The most important causes of processing variation are:

a. The use of impure chemicals which have not been certified; and b. Improper replenishment of processing solutions. Purity of solutions is controlled by a metered flow of fresh chemicals into the system and a like depletion of exercised solution. This procedure must be conducted in a constant mode through precalibrated metering flow device. A process that is allowed to deteriorate and then restored periodically by "shots" or additions of chemicals to the tanks is a poor practice and results in consistent inconsistency.

c. Improper storage of replenishers. Replenishing chemicals are only effective in keeping a process under consistent control, if they have not decomposed during storage. All chemicals should be kept in air-tight containers until set. Tanks which feed the replenishment flowmeters should be covered at all times. Aeration during mixing should be avoided. When mixing chemicals, cold water should be used since heat contributes to the deterioration of the chemical.

d. Contact with active materials during storage or in use. Chemicals can react with certain types of material that will result in contamination. Contact with certain types of plastics and metals rapidly can render chemicals ineffective, if such a situation should persist. For this reason, manufacturers and operators of film processors have incorporated special materials in the handling of the various processing chemicals (see Appendix A).

It should be pointed out that, even in a highly consistent processing operation, there is a certain inherent variability that will be reflected by the chemical analyses and densitometric control readings. No attempt should be made to adjust the chemistry for minute differences.

Such a practice leads to over-control of the system. Such corrective action can lead to more process variation rather than less.

This is borne out by the common processing of a number of strips in one continuous length of film. Densitometric readings on each of these strips will show small differences but, to an over-critical eye, would suggest process variation when, in fact, the processing system was constant (31).

While Koerner (31) addressed the problems of the color process, Williams (32) addressed the problems of sensitometric analysis of the process. Practical sensitometric testing must be simple. For this reason, much of the sensitometry of black and white materials has been reduced to the relationship between logarithmic exposure and image density. This relationship, usually expressed in the classic curve of Hurter and Driffield, is derived from an irreducible minimum of straightforward operations--exposure, processing, and determination of image density.

A surprisingly complete knowledge of a film's photographic properties can be derived from such a test if it is properly specified and conducted. It is natural that similar tests be tried as the basis of the sensitometry of color materials and processes.

A sensitometric Gray scale on a color film results from exposing the film to a series of intensities of white light (stepwedge). The Gray scale exposure, therefore, must be made with the kind of light which white or gray objects reflect and place on the film under conditions of normal use. More exact definition describes the white or gray objects as spectrally non-selective, diffusely reflecting objects.

It has long been a first principle of sensitometric practice that processing of test samples satisfy two requirements. First, it must be repeatable with excellent precision and second, it must be correct in kind.

Variable processing can be used for evaluation of film characteristics only by making some sort of repeated comparison with one or more selected "check" films, simultaneously processed to furnish a base reference (control strip).

Considerable experimental evidence indicates that the best and, quite possibly, the only adequate method of maintaining long-time stability in characteristics of film and processing (each independent of the other) is a combination of a stable reference process and extensive chemical analysis. It is realized, however, that no sensitometric processing machine yet designed is ideal, particularly in its ability to imitate color processing as done in large continuous film strip machines.

Sensitometric processes must be repeatable, not only from day to day, but, if necessary, from year to year. Such repetition can be guaranteed only by identical handling of the film in solutions of identical chemical constitution. A good processing machine will provide identical handling. A perfectly replenished continuous process would provide the identical processing solutions. (Systems available at the time of this writing were sufficient for sensitometric work and the sensitometric references were processed with entirely new solutions mixed from homogeneous reserve stock of chemicals.)

Purpose of analytical densitometry is the determination of individual densities of certain components of the image, such as the densities of the individual red, green, and blue dyes in reversal film.

Sensitometric tests require precise application of a carefully chosen exposure, a correct, precisely controlled color process and densitometric measurements by an accurate, rapid instrument capable of measuring a specific kind of density which can yield significant information (32).

While overcritical processing should be avoided, there is no excuse for carelessness in the densitometric analysis of processed film. If one is to be accurate in the daily plotting of sensitometric control strips, the individual responsible for this practice should be aware of variables and pitfalls in densitometric analysis.

Optical density is defined as the logarithm of the reciprocal of the transmittance of a film as given by the relationship D = log 10 (1/T). If two densitometers disagree, the principal source of disagreement arises from the difference in their spectral responses. The chief cause of the difference is type, age, and unique difference of the filters in the densitometer.

Accuracy means conformance to a recognized standard. In this sense, few commercially available instruments can be said to be accurate as defined by the American Standard for Spectral Diffuse Density of Three Component Subtractive Color Films (PH2 1952).

For process control, an arbitrary choice of filters is permissible. The important thing is that the readings from a given instrument be stable and reproducible so that a change in the process can be detected and interpreted with confidence.

A number of pitfalls exist in the operation of densitometers which can result in erroneous and contaminated readings:

a. A great source of variability in measurements comes from hasty

operation. Failing to "zero" the instrument is a common mistake. Careless handling of the strip involving abrasion, fingerprints, etc., can produce faulty readings.

b. Densitometers should be given an adequate warm-up period--at least 30 minutes for reliable readings.

c. Densitometers that operate on AC modulation usually are especially sensitive to the 100 percent modulated stray light from fluorescent luminaries.

d. Dust on densitometer's optics, including the filters, can cut efficiency and lower precision as amplifiers are forced to run at higher gain.

e. Air conditioning is an important asset rather than a luxury, as far as color densitometers are concerned.

f. Temperature and humidity variations can affect the density of photographic samples as well as the performance of the densitometer (33).

While there may be mechanical and environmental variables that cannot be controlled by the operator, the methodical awareness, handling, and attention to controllable details in making densitometric measurements can yield adequate data for process control.

Summary

This chapter attempted to trace the history of photographic development, emphasizing numerous highlights that have led to evolution and development of motion pictures. In addition, it has touched on a number of technical achievements that have been instrumental in shaping of modern-day motion picture and television news filming industries.

Also included are comparative analyses of films intended for use on television, descriptions of conditions and standards recommended for film processing operations, and a brief description of sensitometric/densitometric analysis as a means of maintaining process control.

The following chapter is devoted to the methodology of this study, using a comparative analysis of processed VNF-1 control strips by the densitometric method.

CHAPTER III

DESIGN AND METHODOLOGY

In order to conduct this study which compares the quality and consistency of film processing services, as performed by Professional Film Laboratories and Commercial Television Stations, that would reflect a degree of credibility to the industry at large, the author elected to select a study sample from a sizable portion of the United States. In keeping with this philosophy, it was considered necessary to conduct the quantitative analysis by a means congruent to that routinely practiced by the industry.

This chapter concerns the design and methodology used in conducting research and includes the rationale and procedures for selecting the sample; the mode, mechanics, and strategy of securing the data; the scientific procedure for reading and converting the raw data to numerical values for study analysis; and the statistical tools required to accommodate the study design.

Sample Selection Criteria

Invitations to participate in this study were sent to 136 commercial television stations and 79 professional motion picture processing laboratories in 29 states, including the District of Columbia.

The television stations were selected from a listing in the Radio and Television Directory (34). The primary criterion for selection was

the existence of a news department, as indicated by a listed news director. Initial correspondence was addressed to that individual. Secondly, the stations selected were all located in medium to large metropolitan areas, indicating a substantial viewer population. Finally, an effort was made to select stations affiliated with one of the three major broadcasting networks.

Of the 136 stations contacted, only 12 were listed as independents. It was felt that Television Stations meeting these three criteria would reflect a strong likelihood of high volume local news coverage and, therefore, a possibly heavy consumer of video news film with an in-house film processing department.

All professional Film Laboratory Processors were selected from telephone book yellow page listings of large metropolitan areas. The selection was based on prominent advertising and the various services offered. Since video news film was on the threshold of becoming a popular motion picture film stock among established movie producers, it was felt that laboratories of substantial size and flexibility might also offer video news film processing. As there was rarely a personality connected with film laboratory advertising, initial correspondence was directed to the supervisor of processing operations.

Selection Process

In an effort to conduct this research as professionally as possible, it was decided that the study should be conducted through the endorsement of the Educational Television Services Department at Oklahoma State University and all initial correspondence was typed on official letterhead of that department. Two letters were drafted for the invitations, one

for each group. A magnetic card typewriter was used to mass produce the two letters in hand-typed style and in business format. The body of the letter introduced the study, gave a brief synopsis of its intent and offered a report of the findings to the participant (see Appendix E).

A form describing the sampling process and requesting information about their processing operation accompanied the letter. Points 7 and 8 were omitted on the forms sent to the Film Laboratories because they were all commercial processors and it was assumed that each lab had a routine procedure of process control (see Appendix E). The completion of this form and its return with an affirmative reply were the final criteria for the study sample. All additional correspondence was addressed to the individual who completed the form (Appendix E).

Of the 136 potential Television Station subjects, 68 responded. Of the respondents, two indicated no interest, 18 no longer processed news film, four did not process their own film, three force-processed as a routine procedure, and five did not process VNF. This left 36 stations as the sample for the television group.

Of the 70 potential Film Laboratory subjects, 31 responded. One indicated no interest, six did not process VNF film, one "addressee unknown," one film service with no laboratory service, one extremely low volume of VNF processing, leaving a sample for the study of 21 Professional Film Laboratories.

With the sample finalized, a letter of notification was drafted and mailed on March 6, 1978, informing each participant of his selection and advising him of the first trial shipment to arrive the following week (see Appendix E).

VNF-1 Control Strips and Trial Shipment

Four 100-foot rolls of VNF-1 control strips were purchased from the manufacturer of the video news film stock. These strips were shipped in dry ice with heavy insulation to inhibit any density or color shift due to pre-processing temperature or humidity variation. Upon arrival, the control strips were frozen and remained at sub-freezing temperatures until thawed for cutting and distribution as recommended by the manufacturer (1).

Trial 1: Packaging and Shipping

It was considered necessary to uniformly package each sample control strip to (1) inhibit any accidental fogging of the emulsion and (2) to protect the strip from impact damage.

For purposes of economics, it was also considered necessary to minimize the weight. Plastic light tight containers with snap-top lids manufactured for 35mm slide film were chosen as the standard enclosure for the control strips because of the availability, weight, durability, and resistance to accidental light leakage and exposure. Two hundred and twenty-eight containers were acquired and labelled in preparation for the three trials, plus a special fourth trial to test for density variation due to mail handling. Small two-inch by four-inch black bags were fabricated from black plastic and black masking tape as light tight security measures for the control strips.

Control Strip Cutting and Packaging Technique

Two hours before opening, control strip rolls number one and number four were removed from the freezer. Rolls number two and number three

remained frozen for later trials. Previous to control strip thawing, the containers for Trial 1 and the mail exposure test were assembled numerically and taped in chronological position, in preparation for packaging. A motion picture darkroom equipped with a counter surface and mechanical film rewinds was secured for the packaging operations.

Each 100-foot roll of VNF-1 control strips contained 1,200 inches of pre-exposed film stock. With a sample of 57 subjects, it was decided the strips would be cut from the rolls in 20-inch lengths to allow for any short cutting by the manufacturer and still provide enough length for leader connections in the processing machine.

First, the darkroom was thoroughly cleaned. Next, a jig was fabricated between the mechanical rewinds consisting of two boxes and several strips of soft cloth film cleaning material. The material then was taped to the counter, soft side up, to protect the film stock from dust and scratches. A small box 1/4 inch by 1/2 inch by 2 inches was taped to the right side as a bump stop measure for the leading end of the film stock. A second box, 1/2 inch by 2 inches by 2 inches was taped to the left side exactly 19 1/2 inches from the right side bump top. A trial strip was cut with black leader to test the jig. The leading edge was drawn from left to right and slid underneath the right bump stop 1/2 inch to keep the film from curling and free the right hand for cutting. A pair of scissors was used to cut the stock flush with the edge of the left side box and the strip of leader was then measured for accuracy.

Sample containers for the mail exposure test then were positioned to the left wide of the jig assembly and the black bags were placed in a drawer below the counter. The room was secured and lighting reduced

to total darkness. Roll number four was opened, mounted on a split reel and placed on the left side rewind, feeding from the top of the roll, emulsion down. The stock was pulled from left to right and cut in the same fashion as the test strip. Each mail test strip was coded by scratching the appropriate code number in the emulsion with a sharp pointed tool.

The strip was then carefully rolled up manually, leading edge out. Care was taken not to cinch the film or to contaminate the strip with fingerprints. A small piece of masking tape was applied to the end of the strip to hold it in a tight curl for handling. A cotton glove was worn on the left hand at all times and the bare right hand was used for handling tools and touched the film only at the edges during the rolling and taping. The strip was then placed into the bottom of a small black bag and the top was folded down. The bag was then placed into the plastic light tight container with the folded opening down, as a protective measure against light leak. The top then was snapped onto the light tight container and placed in a cardboard box to await final sealing.

When all mail test samples were cut and containerized, the door to the darkroom was partially opened and the light was left off. Black masking tape was used to seal each cap as a further measure against accidental light leak. The box of mail test samples was then sealed and stored at room temperature to await shipment.

Trial One samples were cut from roll number one immediately following the completion of the mail test packaging. The technique was identical but there was no need to scratch code the strip as identity could be determined by the return mail. Fifty-seven protective insulated

mailers were purchased for the Trial One shipment. Each mailer was pre-coded for subject identity. A letter of instruction was drafted, outlining the contents and handling procedure for return shipment (see Appendix E).

Standard packing tape was used to attach the mail test container to the lower inside of the mailer with instructions to be left attached and unopened. The first trial sample container, along with the letter of instructions, return address and return postage, were then included and the mailer was sealed.

The mailers were then addressed at the time of sealing. To eliminate confusion, the coded mailer and its contents were assembled and treated as a unit during the packaging. It was requested that the first trial sample be processed on Friday, March 17, 1978, or the last processing day of the work week. The Trial One mailers were stamped FIRST CLASS and mailed on March 10, 1978.

Four weeks were allotted for sample return. This amount of time was necessary to accommodate stragglers and problems in mail service.

Of the 36 television processors and 21 film lab processors qualified for the first trial, 32 television processors returned the sample control strips, completing the trial requirements as per the instructions. All 21 of the film lab processors completed the first trial.

Upon return, all first trial sample containers were removed from the mailers and stored unopened in a closed box. Mail test samples were removed from the mailer and stored in a separate box. After the shipping of the second trial, all mail test samples were processed by a common processor in chronological order and were returned to the experimenter on two separate 100-foot spools. They were visually examined for scratch

code identity then rolled back on the spool, canned, and taped for later analysis.

The second trial was conducted in an identical manner to the first trial but without the inclusion of a mail test sample. Instructions were given to process this sample on Monday, May 1, 1978 (see Appendix E). The second trial was completed as per instructions by 30 of the remaining 32 Television Station processors and 20 of the 21 Film Laboratories.

The third trial was conducted in an identical manner to the first and second trials. Instructions were given to process this sample on Wednesday, July 5, 1978 (see Appendix E). Of the 30 remaining Television Station processors, 26 completed the third trial, setting the group population for the television processors. Of the 20 remaining Film Laboratory processors, 17 completed the third trial, setting the group population for the Professional Film Laboratories.

All processed control strips from the mail test and three trials were spliced together with a 16mm guillotine tape splicer, preserving as much control strip test surface as possible. The control strips were handled at all times with a cotton glove on the left hand. The right hand touched the film on the edges only and was left bare for utility. Each time a control strip was to be removed from a container during any stage of the handling process, the work area was cleaned to minimize dust collection. No provisions were made to filter the atmospheric environment. Once the control strips were fixed chronologically by group and by trial, they were rolled onto spools, placed in cans, and taped shut.

The first analysis of the VNF-1 control strips was a thorough visual examination. Two light sources were used for visual analysis.

A translucent plastic surface with a fluorescent backlight was used for visual observation of color and density variations. Observation was made by taping the manufacturer's reference control strip to the translucent plastic surface and positioning the experimental control strip adjacent to it, density by density.

A 60-watt incandescent lamp was used to identify physical characteristics. Each strip was carefully examined for scratches, sprocket area damage, chemical residue, attached bits of debris, handling damage, water spots, fingerprints, emulsion finish, roller abrasion, clear end (first into the processor), shiny splotches, and static electricity patterns.

When the visual analysis of one trial was completed, all strips were rolled, canned, and taped before another trial was opened. At no time was more than one trial by group opened for analysis during the entire study and no two reference strips were removed from their identifying containers at the same time. This was done to avoid any chance of confusion of references or trial groups.

Density measurements were made using a Super Speedmaster Model T-60D-Sa Digital Densitometer, manufactured by the Electronic Systems Engineering Company of Cushing, Oklahoma. To insure accuracy and consistent performance, the densitometer was taken to the manufacturer and thoroughly checked and calibrated. A factory test density check tablet was provided to maintain proper calibration throughout the entire densitometric reading process.

The densitometer was plugged in and grounded. The instrument remained in this position throughout the reading process. (During the third reading phase, a source light failed and the instrument was

returned to the manufacturer for lamp replacement and recalibration before continuing.)

The Densitometric Reading Process

A standard reading procedure was adopted to minimize unexplained variation in repeated density measurements. The instrument was turned on two hours before readings were to be made. Readings were begun only after the instrument had demonstrated a stabilized posture.

Each VNF-1 control strip consisted of 11 densities, ranging from D-min (Step 1) to D-max (Step 11). Steps 1, 4, 7, and 11 were chosen as the test densities. This is consistent with the standard professional technique of densitometry. A visual pattern was fabricated and taped to the reading surface of the densitometer to position each density step in the center of the measuring light beams.

The three Colors of each Density Level were measured by passing the measured beam through red, green, and blue filters built into the densitometer and selected as needed.

To insure constancy of measurement during regular control strip readings, the instrument was zeroed in neutral and the three colors before reading each strip and calibration checked and adjusted every third strip. The standardized procedure for reading each strip was as follows:

With the source light aperture unobstructed, a stepswitch was depressed, activating a light shield, blocking out all extraneous light and containing only the source light beam. The filter selector was placed in the neutral position and fine-tuned to .00-. The fine-tuning was then reversed until the first .00+ appeared. This constituted the

starting point for instrument calibration. The check plaque was placed in the calibration position and the light shield activated. The calibration control was then adjusted to check plaque standard; in this particular case, a density reading of 3.08. The check plaque was then secured in a protective envelope and the neutral and three colors were fine-tuned to .00+ and ready for reading the strip.

The cleaned and prepared strip was placed on the densitometer base and aligned with the pattern to read density number one. The red filter was selected and light shield activated. The reading was notated and the selector rotated to the green filter. The green reading was notated and the selector rotated to the blue filter position. The blue reading was notated, completing readings on Density 1. The light shield was raised and the strip advanced to the Density 4 position. The light shield was then activated and the reading order was reversed. Blue first, then green, then red. The cycle was then repeated for Densities 7 and 11. The instrument was then zeroed for the next control strip.

Because of a concern for measurement contamination caused by dust and chemical residue from various processors, all control strips were cleaned with Ecco 1500 film cleaner. To maintain this treatment as a constant, the reference strips were treated identically. A densitometric test showed no measurable difference between treated and untreated film as detectable by the measuring densitometer.

The Manufacturer's Reference Standard

To establish the reference strip standard, the instrument was prepared as per the standard reading procedure and the reference control strips from Trials One, Two, and Three were read and notated. The mail

test reference was not measured because the mail test strips were to be averaged against themselves and not against the reference. Readings on the three trial references were conducted once daily for six days.

The six readings were averaged to arrive at the standard for each trial. Of the six readings, no single color of a given density exceeded a difference of .02 which was within the tolerance of the instrument as stated by the manufacturer.

The mail test roll was the first to be measured. All strips were read as per the standard reading process with the exception of Television Processor number 29. This strip, for some reason, had been opened and badly fogged, despite the safeguards. Once the mail test strips had been read and recorded, eight strip readings were selected at random from each group. The readings were averaged to arrive at a standard for each group. Under normal experimental conditions, one standard would have been sufficient but it was learned that the two groups had been common processed at different times, therefore needing two standards.

The common standard was then used to calculate the deviations of each mail test strip. Once calculated, the strips were plotted on the manufacturer's process record form Y-55.

Each of the three trials were read in the same manner as previously described. The television processor group of each trial was read first at a single sitting. The film lab group was then read following an hour's break, also at a single sitting. Each of the three trial readings was conducted on separate days in consideration of experimenter fatigue.

To control instrument and environmental variation, the entire three-trial reading process was repeated three times and the three readings of

each Color and Density were averaged to arrive at a score to be measured against the film manufacturer's standard.

During the averaging, if any of the three readings for a given Color in a given Density Level exceeded .05 difference, the entire strip was re-read and matched against the three original readings of that trial to determine the average. The odd reading then was rejected. Several such readings occurred just before the failure of the densitometer source light. To reduce the error, the entire Film Laboratory group's third reading was repeated and the faulty readings discarded.

The averaged readings were compared to the manufacturer's standard and differences were notated as per standard practice in the film processing industry. The differences were then plotted on a form Y-55 graph, Density by Color by Trial.

To verify the performance of the densitometer used in the study, the third Trial control strips of both processor groups was re-read on a Speedmaster TRC-60D Universal Digital Densitometer, equipped with status AA filters prepared by the instrument manufacturer. Readings compared closely but a few showed a marked difference. It was noted the building in which the back-up readings were conducted was being painted using an electrically powered compressor and line voltage fluctuations may have been responsible for the variation in the readings. Therefore, a second redundant reading was conducted at a Professional Film Laboratory, using a MacBeth dial-type Quanta Log densitometer, Model TD-204AM, equipped with calibrated status A-58 filters. The readings from both back-up trials were logged and plotted against the third Trial readings for instrument verification.

Latent Image Shift Test

Trends in the measurements suggested the possibility of a latent image shift in the factory-exposed control strips due to extended time and temperature differences incurred between the packaging and processing events. These intervals may have fluctuated between 7 and 14 days.

To test for latent image shift characteristics, four more sample strips were prepared by the standard procedure from the third trial roll which had been kept refrigerated since the third trial packaging procedure. All four control strips were scratch coded during packaging for identification after common processing. The four strips were then given individual treatments.

Test strip number one was placed back in a frozen state and kept for the 10-day experimental period as the control standard. Test strip number two was at room temperature in a residential living room, atop a television set. Test strip number three was mailed from Oklahoma to Florida and returned to test for mail exposure and temperature/humidity fluctuation characteristics. Test strip number four was taped to a residential front porch structure and exposed to natural elements for the entire 10 days. At the end of the 10-day experimental period, all four test strips were processed by a common processor at the same time. The test was plotted on a manufacturer's form Y-55 with the test strip number one adopted as the standard. Adopting the frozen sample as the standard rendered all processor variables as constants and the three experimental strips then could be compared on the basis of simple deviation.

Statistical Analysis Procedure

Since processing consistency over the three trials was of major interest in this study, a "Treatments-by-Subjects" two-way analysis of variance design was selected as the statistical tool to determine group, as well as individual processor consistency. This procedure was employed to determine Color by Density characteristics across the three consistency Trials.

To test for differences between the two groups of processors, a Type VI analysis of variance was selected and rotated to accommodate the two groups (Television Stations and Film Laboratories) against the three possible combinations of Color, Density, and Trials.

Assumptions

In order to conduct this study, it was necessary to request each participant to carry out the processing of VNF-1 control strips in a manner which would reflect the normal day-to-day practices of each processing operation. For purposes of equality in the interpretation of the data obtained from these processors, the following assumptions were made:

1. All VNF-1 control strips were processed on or about the date requested.
2. All strips were equal when submitted to the participant's processing system.
3. All control strips were processed along with regular work and no effort was made to bias the process.
4. All participants were operating their processing machines in a mode for the <u>normal</u> process of Video News Film.

5. All readings were honest and attributable to processor variation.
6. The subjects consenting to participate in this study are representative of the professional stature of their respective industries.

Details relevant to handling and measurement procedures of the processed control strips were systematically observed in order to insure maximum accuracy of the resulting densitometric readings.

Limitations of the Study

This research was conducted with a final test sample consisting of 26 Television Stations and 17 Professional Film Laboratories located in 21 states and the District of Columbia. All Television Station Processors completing the study task requirements were national network affiliates and all Film Laboratories operated on a five-day per week, commercial basis.

The quantitative analysis, in this research, was conducted under a systematic densitometric procedure that is consistent with those recommended by the film stock manufacturer and routinely used by professionals in the industry.

Within these guidelines of selection and procedure, there were three primary limitations to this research:

1. The study population was limited to the consenting respondents who successfully completed the test strip processing for all three Trials.
2. The research data were limited to the processing performance of the participants concerning the VNF-1 process only.

3. The quantitative measurements of the control strip densities were limited to the accuracy of the measuring instrument which was set by the manufacturer at plus or minus .02 density units and repeatable to within plus or minus .01 density units (35).

Generalization to this study should be congruent with the sample and conditions previously described.

Summary

The author has attempted to describe the sample selection criteria, the study design and testing strategy, the control strip preparation, data acquisition and measuring procedures; the accuracy safeguards employed in those procedures; and the statistical tools selected for the analysis of the data. The following chapter is addressed exclusively to the findings of this study.

CHAPTER IV

RESULTS OF THE STUDY

Introduction

The analysis of data regarding the multiple trial processing of VNF-1 control strips by Television Station and Professional Film Laboratory processors participating in this study is presented in this chapter. The purpose of this research was to collect and compare data from Television Station and Film Laboratory processing operations relative to processing consistency as measured over three Trials against the manufacturer's standard.

The author posed two questions to be answered by this research. They were:

1. What are the relationships between various Television Station Processors and processing quality as measured by Density and Color characteristics?
2. What are the relationships between processing quality and consistency of Television Stations, in general, as compared to the processing quality and consistency of Professional Film Laboratories?

In order to select a sample for this study, invitations were sent to 136 commercial Television Stations and 79 Professional Motion Picture Processing Laboratories in 29 states, including the District of Columbia. Of the 136 Television Stations, 68 responded. Of the

respondents, 36 consented to participate in exchange for a report of the results upon completion of the study. Of the 32 respondents who declined to participate, 18 (56 percent) indicated they had made the conversion to E.N.G. (Electronic News Gathering) and had discontinued the use of film altogether. The author has reason to believe that in the period following the data collection for this study, several of the participating subjects have also made the conversion to E.N.G. and reduced or eliminated the processing of motion picture film. Of the 79 Film Laboratory invitations, 31 responded and 10 chose not to participate, leaving 21 Film Laboratories for the sample.

Control Strip Mailing Procedures

VNF-1 control strips which were pre-exposed by the manufacturer under standardized sensitometric procedures were purchased to obtain the study data, four 100-foot rolls in all. Two of the four rolls were cut into individual strips for shipment to each of the subjects of both groups. The first roll served as the test roll to be processed by the subjects for later analysis. The second roll was scratch-coded and included in the shipment with instructions not to be processed. Its purpose was to determine Density variation, if any, that might be attributed to travel through the mail. The first Trial was mailed on March 10, 1978, with instructions to be processed on March 17, 1978. This was done in an effort to hold the processing event constant, across the sample of both groups.

After a four-week period, the mailer envelopes, returned up to that time, were opened and the processed test samples removed and stored together in their individual light tight containers. The scratch-coded

mail test samples were processed by a common processor and set aside for densitometric analysis. Trials Two and Three were conducted in the same manner but without a mail test.

Upon completion of the three Trials, 26 of the participating 36 Television Stations and 17 of the 21 participating Film Laboratories completed the tasks required for study analysis. While all returned strips were measured densitometrically and recorded, only those completing all three Trials were considered in the statistical analysis of the study.

Densitometric Analysis Procedure

Each control strip from each subject on each Trial was measured by the densitometric process three times and the three readings averaged to arrive at the official measurement for study purposes. Readings were taken on Colors Red, Green, and Blue, within Density Levels 1, 4, 7, and 11 of the VNF-1 control strips. The densitometer was zeroed in neutral and in each of the three Colors before reading each strip and calibrated to the check plaque every third strip. This was done to verify mechanical and electronic consistency within the measuring instrument.

As a measure against unexplained variation due to latent image shift caused by post-packaging time and environmental conditions, four additional strips were cut from the frozen remains of roll number three, assigned initially to the third Trial. The VNF-1 control strip stock was thawed and cut into four equal strips (20 inches in length) packaged and submitted to four separate physical treatments. After 10 days, all four were processed by a common processor and compared for density variation.

Mail Exposure Test

In an effort to maintain an overall handling consistency in this study, the two processor groups were kept separate in all phases of data analysis. The commonly processed control strips for the mail exposure test were processed as groups at different times, requiring a separate averaging for each group.

The procedure for arriving at a standard for each of the mail exposure test rolls was as follows:

1. Each control strip was densitometrically analyzed and recorded. This included the Colors Red, Green, and Blue for Density Levels 1, 4, 7, and 11. The reading process was conducted as defined in Chapter III.
2. The mean Density then was calculated from eight randomly selected control strips per group for each of the 12 reference Densities (3 colors x 4 density levels = 12) and was adopted as the standard reference for that group.
3. Each strip reading was then plotted on a manufacturer's record form Y-55 against the mean standard.

The mean scores are compared in Table I. While the Density readings from the Film Laboratory group are slightly higher, the overall variation would not exceed what would be expected from a well controlled processing system. It was considered that what variation did take place could be attributed to slight drifts in the processor chemistry between the separate processing of the two groups. In no case did any of the scores deviate from the mean standard more than .05 among the Film Laboratory participants, in any of the three Colors or four Density Levels. This held true for the Television Station processors as well, with one

exception. Television processor number 25 showed a +.07 deviation on the Color Red in Density Level 7 (see Figures 1 and 2).

TABLE I

MAIL EXPOSURE TEST MEAN SCORES

Density	Color	Television Stations	Film Labs
1	Red	.19	.19
	Green	.20	.21
	Blue	.23	.23
4	Red	.69	.71
	Green	.56	.58
	Blue	.64	.65
7	Red	2.44	2.46
	Green	1.98	2.02
	Blue	1.91	1.93
11	Red	3.14	3.14
	Green	2.97	2.99
	Blue	2.64	2.67

If either group was looked at as a single processor, the record would show an extreme degree of consistency through all Colors and Density Levels. In this case, however, the only variable beyond the common processor of the test strips was the mail traffic which, within the scope of this study, exhibited no significant effect upon film density variation.

Latent Image Shift Findings

Since the four strips were cut from the same roll (number three), the first strip receiving the frozen treatment was adopted as the

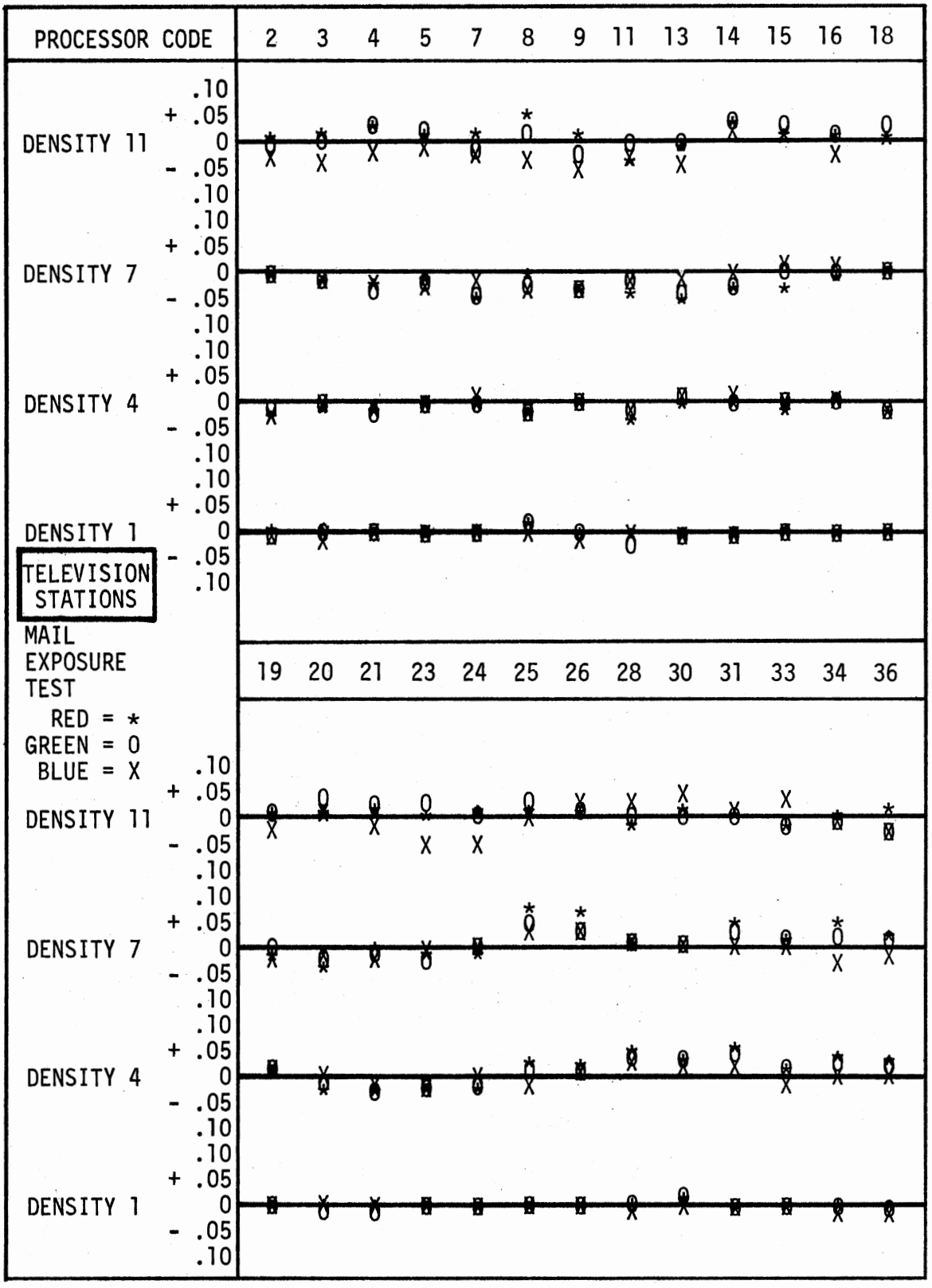

Figure 1. Mail Exposure Test, Television Stations

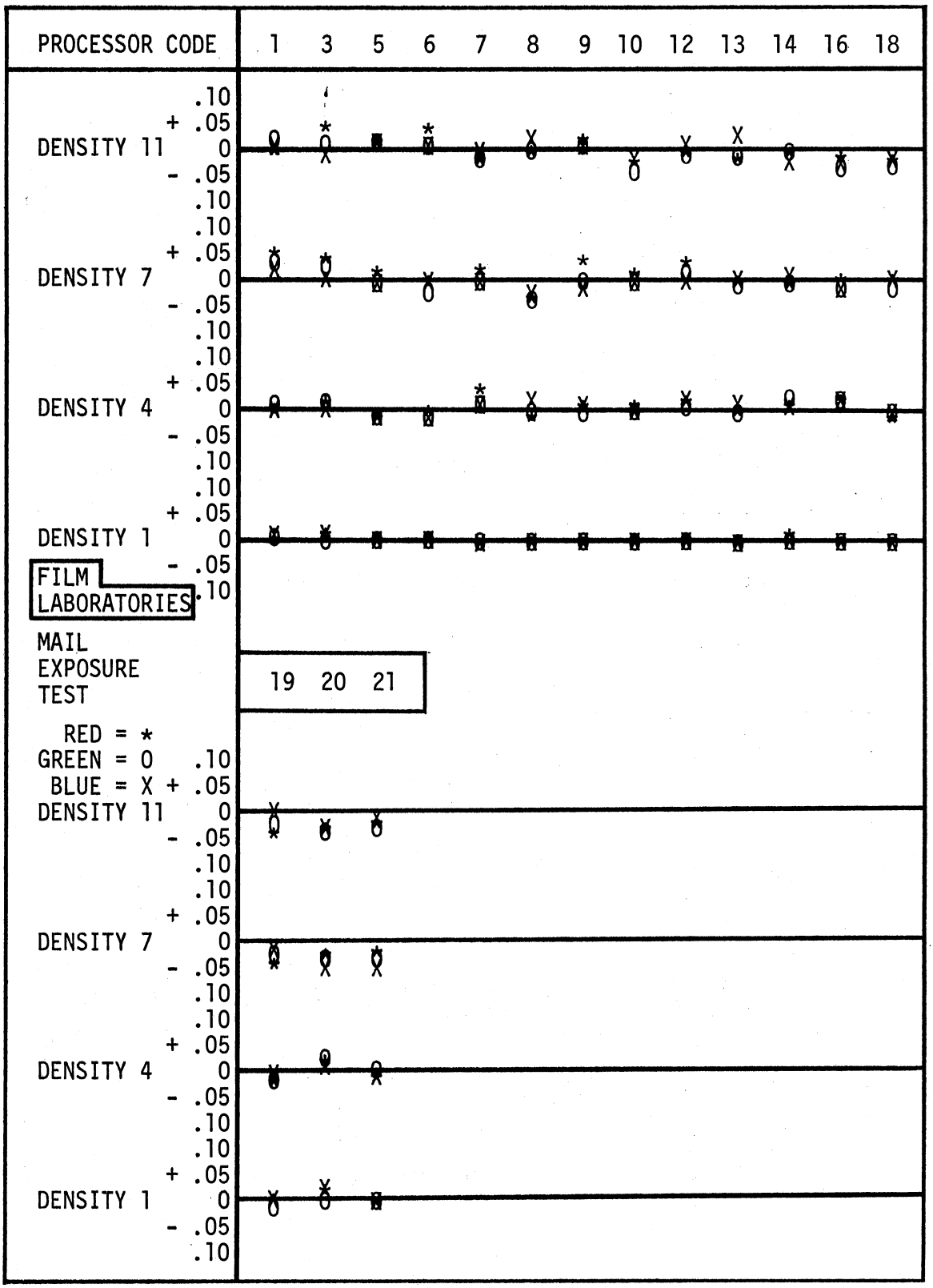

Figure 2. Mail Exposure Test, Film Laboratories

standard because it would, under frozen conditions, remain as close to fresh as possible. All four strips were common processed and each strip was read and recorded in a single sitting. The densitometer was zeroed and calibrated before each strip reading. This procedure was repeated five times and averaged to determine the official readings for the study. Strip number one then was adjusted to the zero standard and strips two, three, and four were plotted against that standard.

The only noticeable difference in the graphic analysis occurred in strip number two on Density Levels 4 and 7. In Density Level 4, Colors Red and Blue plotted at +.06 and +.05 respectively from the standard while Green plotted at +.03. In Density Level 7, however, Red and Green plotted at +.08 with Blue slightly below with a +.06. These differences are not overly dramatic but they do establish some degree of emulsion sensitivity to environmental conditions which might have contributed to some of the unexplained variance detected during the study. It should be noted that the only noticeable deviation in this latent image shift test was in the direction of <u>increased</u> density and negative to random exposure influence. It might also be noted that the common processor for the four test strips was a participant in the study (TVP-25) and the densities of these strips, including the frozen sample, were far below those of the control strips processed by this processor for the three trials (see Figure 3).

Statistical Analysis of Densitometric Data

In this study, which called for a multi-variate analysis, the author not only was interested in the <u>main</u> differences between levels of variables, but in the <u>interactions</u> of levels of two or more variables.

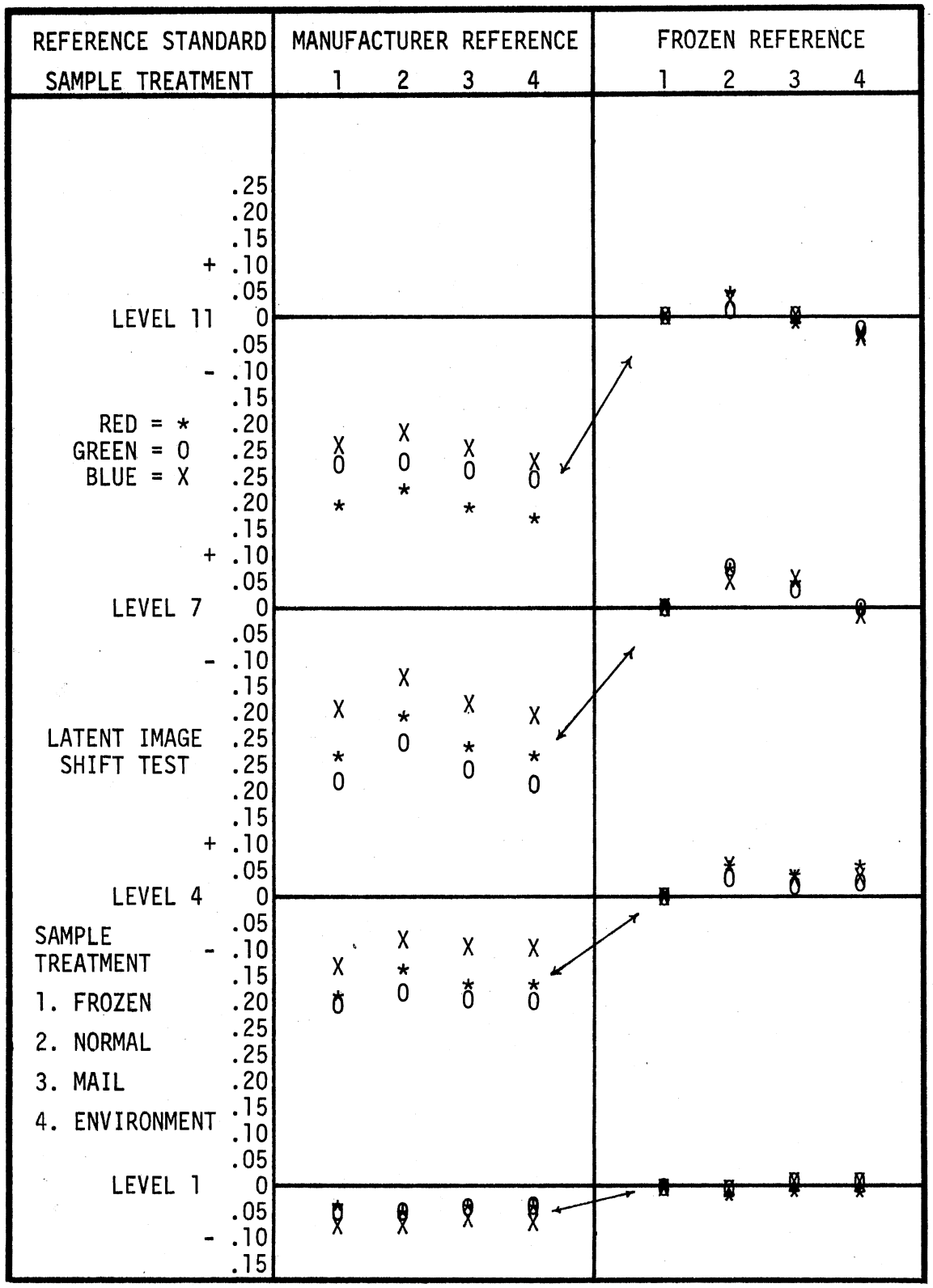

Figure 3. Latent Image Shift Test

The reader is reminded that the dependent, or response variable, comprised the simple units of deviation from the company standard, as revealed in each of the three VNF-1 control strips processed by the 43 respondents. No provisions were made for directional deviation (plus or minus) above or below the measured densities of the company standard which was established at zero (.00) for this study in accordance with conventional recommended procedure.

The four independent variables were: (1) Processors--Television Stations and Film Laboratories; (2) Colors--Red, Green, and Blue; (3) Density Levels--1, 4, 7, and 11; (4) Trials (Numbers One, Two, and Three conducted six to nine weeks apart). The design, then, called for a 2 x 3 x 4 x 3 = 72-fold analysis paradigm, as shown in Table II.

TABLE II

FOUR-VARIABLE, 72-FOLD ANALYSIS PARADIGM

		Density											
		1			4			7			11		
		Color											
Processors	Trials	R	G	B	R	G	B	R	G	B	R	G	B
Television Stations	1	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-	-
Film Laboratories	1	-	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-	-

Table II shows that each Television Station and Film Laboratory Processor completed 36 tasks, in that there are 36 combinations of three Trials and three Colors within four Density Levels (3 x 3 x 4 = 36).

Twenty-six Television Stations and 17 Film Laboratories participated in the study. Each of the 36 property spaces in Table II that pertain to Television Stations would comprise the mean, or average, of the actual deviations recorded from the test control strips processed by the 26 Stations. Likewise, for the spaces comporting to the 17 Film Laboratories. Thus, a total of 1,584 actual deviation scores comprised the raw data for ensuing analyses (36 x 26 = 936 Television Station deviation scores plus 36 x 17 = 612 Film Laboratory deviation scores).

From the data supplied for Table II, the following information was retrieved:

1. Differences in mean deviations from the standard between Density levels.
2. Differences in mean deviations from the standard between Colors.
3. Differences in mean deviations from the standard between Trials.
4. Differences in mean deviations from the standard between Processors.
5. First- and second-order interactive effects of any two or more variables on mean deviations.

Prior to these "major" analyses, the author will present data bearing on the over-all portrait of the extent of Processors' deviations from

the standard, as well as their processing consistencies from Trial to Trial.

Mean Deviations from Company Standard:

An Overall View

In total, 72 mean deviations from the standard were derived from data pertaining to the four study variables. In other words, there were 72 possible combinations of the Processor, Color, Density Level, and Trial variables.[1] Table III lists the mean deviations, as well as the mean totals (MT) and grand mean totals (GMT), for each variable and combinations thereof.

Overall, Film Laboratory and Television Station processors deviated an average of .159 from the standard. All but two mean scores in Table III departed significantly from the standard.[2] On the average, Film Laboratory Processors did not deviate significantly on the Blue Color during Trials One and Three within Density Level 1.

This overview from Table III, then, reveals that the Film Laboratory Processors, on the average, departed significantly from the standard in

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[1]The 72 mean deviations in Table III were based on 1,584 individual deviation scores, i.e., 17 Film Laboratory Processors actually completed 36 Trials for a total of 612 scores, while the 26 Television Station Processors completed 36 Trials for a total of 972 scores. The figure of 36 Trials arises from the fact that scores were recorded for each of the three Colors and for each of the four Density Levels on each of the three Trials.

[2]One-sample t-tests were used to determine probability levels of mean deviations. Observed mean deviations were compared with the company standard which was a zero mean deviation. Therefore, each mean deviation was subjected to a test for significance of departure from zero.

TABLE III

MEAN DEVIATION FROM COMPANY STANDARD: BY TYPE OF PROCESSOR, COLORS, DENSITY LEVEL, AND TRIALS

Density Level	Color	Film Laboratories				Television Stations				GMT
		T-1	T-2	T-3	MT	T-1	T-2	T-3	MT	
1	Red	.070	.059	.065	.065	.058	.047	.055	.053	.057
	Green	.045	.036	.046	.042	.049	.044	.049	.047	.045
	Blue	.043	.041	.041	.042	.055	.044	.053	.051	.047
	MT	.053	.045	.051	.050	.054	.045	.052	.050	.050
4	Red	.179	.146	.161	.062	.159	.160	.150	.156	.158
	Green	.130	.106	.128	.121	.141	.140	.148	.143	.134
	Blue	.132	.122	.112	.122	.120	.113	.115	.116	.118
	MT	.147	.174	.134	.135	.140	.138	.138	.138	.137
7	Red	.160	.119	.115	.131	.192	.183	.190	.188	.166
	Green	.163	.162	.182	.169	.180	.207	.202	.196	.186
	Blue	.162	.116	.165	.148	.252	.232	.261	.248	.208
	MT	.162	.132	.154	.149	.208	.207	.218	.211	.187
11	Red	.188	.122	.161	.157	.289	.340	.319	.316	.253
	Green	.144	.183	.155	.161	.252	.349	.296	.299	.244
	Blue	.245	.161	.210	.205	.362	.348	.350	.353	.295
	MT	.192	.155	.175	.174	.301	.346	.322	.323	.264
	GMT	.138	.114	.128	.127	.176	.184	.182	.181	.159

Underlined deviations not significantly different from company standard. All others $p < .05$ at most.

about 95 percent of their 36 tasks, while the average Television Station Processor deviated significantly on all tasks. The average Television Station deviated .181 from the standard, with a range from .044 on Trial Two, Color Green within Density Level 1 to .362 on Color Blue within Density Level 11. Film Laboratories, on the average, departed .127 from the standard with a range from .036 on Trial Two, Color Green within Density Level 1 to .245 on Trial One, Color Blue within Density Level 11. The smallest and largest deviations, then, were recorded on the same Trials, Colors, and Density Levels for both types of processors.

The above figures, however, answer only a small segment of the body of research questions. The author sought to determine if the grand mean total deviation, for example, varied by Processor, Color, Density Levels, and Trials. Perhaps most importantly, an effort was made to determine if mean total deviations on any single variable was due to its interaction with levels of another variable or variables.

Forthcoming analyses addressing the above and other questions were based on the data from Table III. In addition to quantitative analyses and interpretations, the author will inject qualitative findings and comments as they are deemed relevant to the more systematic data.

Processing Consistency Across Trials

Table III showed that Processors departed significantly from the standard on all but two tasks. But these findings refered to "Processors on the average," not to individual processors. Nor did these findings refer to the consistency in processing from Trial to Trial.

Put another way, let's say Processor No. 1 showed an average .040 deviation from the standard, while Processor No. 2 showed .110. Is this

a true picture of the difference between deviations of the two Processors? The answer is probably "yes" if Processor No. 2 showed substantially greater deviation on all three Trials. The same holds true when comparing any two Processors' deviations. In such tests of response consistency, the investigator is simply asking if the observed differences among individual respondents--in this case, Processors--are true differences, or merely chance fluctuations. If the variation-between-subjects/chance-fluctuation ratio is significant, then the present investigator could be confident, within the limits of this study, that whatever the degrees of departure from the standard, the Processors (as individuals) were consistent across all three Trials; at least a substantial number of them were. This says nothing about the magnitude of the deviations--only that at least some processors differed and the differences were in the same direction across all three Trials.

Checks on processing consistency were run on each type of processor, by each Color and Density Level--24 tests in all.[3] Results are shown in Table IV. One can consider the F-ratios under the "between-subjects" column of Table IV as rough indices of the degree of processor consistency. For example, the Television Station Processors were most consistent in their processing of Green within Density 7, with an F-ratio of 10.22.

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[3]This statistical test, called the "Treatments by Subjects" design, is appropriate when two or more treatments are given the same subjects (36). In this case, the treatments were the three Trials which repeatedly measured the processing deviations of the same individuals. Twelve tests were run on the 26 Television Station Processors to determine their individual consistency in processing each Color within each Density Level. There were 12 combinations of Colors and Density Levels (3 Colors x 4 Density Levels = 12). Each test, then, revealed if there were significant differences among the 26 Television Station Processors. An additional 12 tests were run on the 17 Film Laboratory Processors.

TABLE IV

SIGNIFICANCE LEVELS OF MEAN DEVIATIONS FROM COMPANY STANDARD: BETWEEN SUBJECTS AND TRIALS FOR 12 COMBINATIONS OF DENSITY LEVEL AND COLOR

Processor	Density	Color	F-Ratios Between Subjects*	Probability Level	F-Ratios Between Trials**	Probability Level
TV	1	Red	5.10	.01	1.00	n.s.
TV	4	Red	6.24	.01	.23	n.s.
TV	7	Red	7.04	.01	.06	n.s.
TV	11	Red	8.91	.01	1.80	n.s.
TV	1	Green	3.68	.01	.33	n.s.
TV	4	Green	7.93	.01	.12	n.s.
TV	7	Green	10.22	.01	.70	n.s.
TV	11	Green	8.11	.01	8.61	.01
TV	1	Blue	3.80	.01	1.80	n.s.
TV	4	Blue	5.30	.01	.09	n.s.
TV	7	Blue	7.11	.01	.51	n.s.
TV	11	Blue	8.22	.01	.10	n.s.
FL	1	Red	17.27	.01	1.00	n.s.
FL	4	Red	8.75	.01	.42	n.s.
FL	7	Red	6.56	.01	.73	n.s.
FL	11	Red	2.60	.01	2.46	n.s.
FL	1	Green	22.00	.01	.71	n.s.
FL	4	Green	12.33	.01	.55	n.s.
FL	7	Green	5.09	.01	.30	n.s.
FL	11	Green	5.39	.01	2.50	n.s.
FL	1	Blue	28.80	.01	.00	n.s.
FL	4	Blue	13.68	.01	.39	n.s.
FL	7	Blue	3.95	.01	1.94	n.s.
FL	11	Blue	2.12	.05	4.42	.05

*df = 25/50.

**df = 2/50.

From Table IV, it is obvious the Processors were consistent in test control strip handling from Trial-to-Trial. Differences in deviations from the standard as large as those observed among the respondents, after three processing Trials, would not have occurred by chance alone more than one time in 100. This was the case for all Colors within all Density Levels. Furthermore, there were no significant differences among the mean deviations of the three Trials in 22 of the 24 consistency checks. This is another indication of substantial consistency in processing.

However, a clearer picture of relative processing consistency is shown by reliability coefficients for the Television Station and Film Laboratory Processors as shown in Table V. These reliability coefficients can be viewed as coefficients of consistency in processing. They simply present the percentage of the observed difference uncontaminated by that due to random fluctuation. For example, in Table V, the Television Station Processors show a consistency coefficient of .80 on their Trial-to-Trial processing of the Color Red within Density Level 1. The observed variation between Processors, as revealed by variance analysis, was .0051 while the variance due to random fluctuation was .0010. Thus, .0051 - .0010/.0051 = .80. This means that 80 percent of the variation in deviations among the 26 Television Processors was due to real differences in their processing procedures and/or concomitant conditions.

Table V shows that Television Station respondents were equally consistent in their processing of Colors Red and Green (with coefficients of .85) but a little less consistent on Color Blue (with an .82).

They were also similarly consistent, from Trial-to-Trial, within Density Levels 4, 7, and 11. Least (yet significant) consistency was

shown within Density Level 1, especially on Colors Green and Blue. Overall, 84 percent of the difference observed among Television Station Processors, regarding their degrees of deviations from the standard, were true differences.

TABLE V

RELIABILITY COEFFICIENTS OF 26 TELEVISION STATION PROCESSORS, ACROSS ALL THREE TRIALS BY EACH COLOR AND DENSITY LEVEL

Density Level	Red	Green	Blue	Mean Variance
1	.80	.73	.74	.76
4	.84	.87	.81	.84
7	.86	.90	.86	.87
11	.89	.88	.88	.88
Mean Variance	.85	.85	.82	.84

The picture differed considerably among Film Laboratory Processors, although their overall reliability, or consistency, in processing from Trial-to-Trial was nearly identical (.83) to the Television Stations as shown in Table VI. Like the Television Stations, the Laboratories were more consistent in their overall deviations on Colors Red and Green (.83 and .87, respectively), but a little less consistent on Color Blue; but most of the similarity ends there.

In fact, the Television Stations and Film Laboratories were negatively related in consistency of processing the 12 combinations of

Colors and Density Levels. Correlation between the 12 corresponding entries in Tables V and VI was $-.67$, $df = 10$, $p < .05$.

TABLE VI

RELIABILITY COEFFICIENTS OF 17 FILM LABORATORY PROCESSORS, ACROSS ALL THREE TRIALS BY EACH COLOR AND DENSITY LEVEL

Density Level	Red	Green	Blue	Mean Variance
1	.94	.95	.97	.95
4	.84	.92	.93	.91
7	.85	.80	.74	.80
11	.62	.81	.53	.65
Mean Variance	.83	.87	.79	.83

A surface scan of Table VI, in contrast to Table V, shows that diametrically opposite to Television Stations, the Film Laboratories were more consistent in processing within Density Level 1 and least consistent within Density Level 11. The lesser stability on Density Level 11 appeared in the processing of Colors Red and Blue.

More specifically, the two largest differences between the Television Stations and the Film Laboratories was the latter's relatively erratic handling of the Red and Blue Colors on Density Level 11. On the other hand, the Film Laboratories were considerably more reliable than the Television Stations in processing Colors Green and Blue on Density Level 1.

Variations from the Company Standard

by Type of Processor

Thus far the author has dealt--systematically, at least--only with deviations from the standard by all Processors on each of the 36 tasks, and with the consistency of Processors in handling test control strips from Trial-to-Trial for each Color within each of the four Density Levels.

Nothing has been said about relative mean deviations on Color, Density Level, or Trial variation by type of Processor. For example, suppose the amount of deviation from the standard between Density Levels is significant. Could it be that a particularly large deviation within a particular Density Level is attributed mostly to Television Stations rather than to Film Laboratories? Or, perhaps there is more deviation on one particular Color within a Density Level or on a Trial.

The following data were based on several correlated factorial analyses of variance which took into account not only overall differences in mean deviations on different Trials, Colors, or Density Levels, but between types of Processors. Additionally, the analyses revealed whether mean deviation differences between the levels of one variable were due to the interaction of that variable with another.

The design called for repeated measures by the Color, Density Level, and Trial variables, which in turn were rotated in combinations of two and juxtaposed against the two assigned Processor variable levels. To clarify, three variance analyses were run as follows: Processor-by-Density Level-by-Color; Processor-by-Density Levels-by-Trials; and

Processor-by-Color-by-Trials.[4]

Disregarding the type of Processor (Television Station or Film Laboratory), the author sought out the main and interactive effects (if any) of Color, Density Levels, and Trials of and on the mean deviations from the standard. For example, if the mean deviation on Density Level 1 was greater than that on Density Level 4, was this more evident on a particular Color? Trial? Or both?

The only overall significant differences in deviations from the company standard were among Density Levels ($F = 52.24$, 3/117, $< .001$). Post hoc differences-between-the-means tests indicated a difference as large as .035 between the mean deviation of any two Density Levels would occur by chance less than five times in 100 replications.

Table VII shows the mean deviations from the standard was greatest on within Density Level 11, followed by Density Levels 7, 4, and 1 in descending order. Their mean deviations were .264, .188, .136, and .050, respectively.

The findings were not this clearcut, however. Table VII indicates that Television Stations, on the average, tended to deviate more from the standard than did Film Laboratories ($F = 3.53$, $df = 1/41$, $p < .05 < .10$). This was related mostly to the Television Stations' relatively large deviation within Density Level 11, compared to the Film Laboratories

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[4]Called a Type VI, the analysis of variance design in this study combines a two-factor, correlated-group with the randomized design. Instead of treating Processors as a single group, they are "subdivided" into Television Stations and Film Laboratories for comparison of their processing performance under the treatment conditions. The conditions are the pairs of rotated variables, i.e., the 12 combinations of Color-by-Density Level, Color-by-Trials, and Trials-by-Density Level variables.

(.323 vs. .174). The deviation by Television Stations within Density Level 11 was nearly twice that of the Film Laboratories. In fact, the high deviation by Television Stations within Density 11 contributed most to that level's overall higher departure from the standard. The Film Laboratories did not differ significantly in the amount they deviated among different Density Levels.

TABLE VII

MEAN DEVIATIONS FROM THE COMPANY STANDARD:
PROCESSORS BY DENSITY LEVELS

Processors	Density Levels 1	4	7	11	Mean Totals
Television Stations	.050	.137	.211	.323	.180
Film Laboratories	.049	.135	.153	.174	.128
Mean Totals	.050	.136	.188	.264	.160

Type of Processor was not the only variable that differentially contributed to the mean deviation differences among Density Levels. Color was involved with an interaction with Density Levels ($F = 31.00$, $df = 6/235$, $p < .001$) as shown in Table VIII.

Post hoc between-the-means tests revealed a difference as large as .072 between any two mean deviations within Table VIII would occur by chance less than five times in 100.

Taking the Density Levels in order, one can see where the mean totals need qualification due to interaction. Density Level 11, for

example, showed significantly greater mean total deviation than Density Level 7, 4, or 1. Was this true for all Colors within Density 11? No, not when compared with Density Level 7. Density Level 11's mean deviation was greater than Density Level 7's mostly because of relatively higher deviations on the Red and Blue Colors. There was no significant difference between Density Levels 11 and 7 on Green. Likewise, Density Level 7 showed a significantly higher mean total deviation than Level 4, due to the relatively high deviation on Color Blue. Differences between Density Levels 7 and 4 were not significant on Red and Green.

TABLE VIII

MEAN DEVIATIONS FROM THE COMPANY STANDARD:
COLOR BY DENSITY LEVELS

Colors	1	4	7	11	Mean Totals
Red	.057	.155	.170	.253	.159
Green	.045	.134	.186	.244	.152
Blue	.047	.118	.209	.296	.168
Mean Totals	.050	.136	.188	.264	.160

Density Level 11's claim to the highest mean total deviation then held true across the board only against Density Levels 1 and 4. Density Level 7's second highest mean total deviation held across all Colors only in comparison with Density Level 1. Density Level 4's third highest

mean total deviation was "pure," as was Density Level 1's lowest mean total deviation.

With no other significant differences revealed through variance analysis, the author concludes that Color and Trials, by themselves, were not significantly related to the degree of deviation from the company standard. Nor did Trials have any effect on the deviations among Colors or between types of Processors. Color, at the same time, was not related to Processor deviations or to deviations among Density Levels.

Qualitative Observations

When observing the Processors in terms of individual performance one can see evidence of the previously mentioned, wide-spread variance. Figures 4 through 9 graphically illustrate the densitometric measurements recorded and plotted for each Processor, by group and by Trial. Each of these comparative performance charts establishes the straight horizontal line of the film manufacturer's standard, and deviations by Color are indicated from that standard by lines drawn to the plots. A scale of densitometric units, covering a normal processing range, measures plus or minus density at each Density Level and is located vertically at the left of the chart. The Processor position and identification code are located across the top of the chart and define the performance of each given Processor within the group from left to right.

The only criterion used for this study, and for measuring processor performance, was the simple deviation from the standard which is indicated across the bottom of the chart with increasing deviation to the right. While these charts show only approximate Density-by-Color

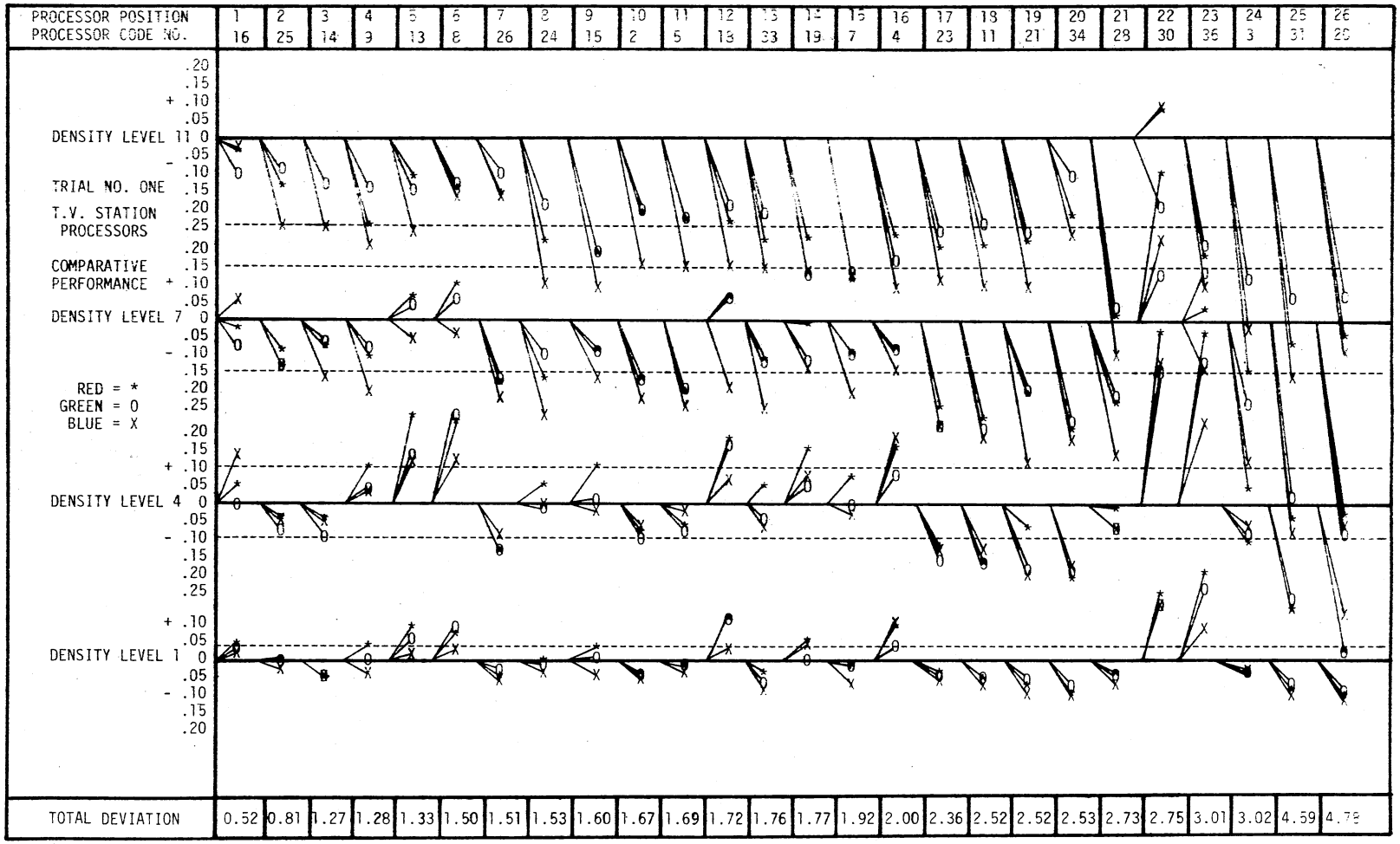

Figure 4. Television Station Processor Comparative Performance Chart, Trial One

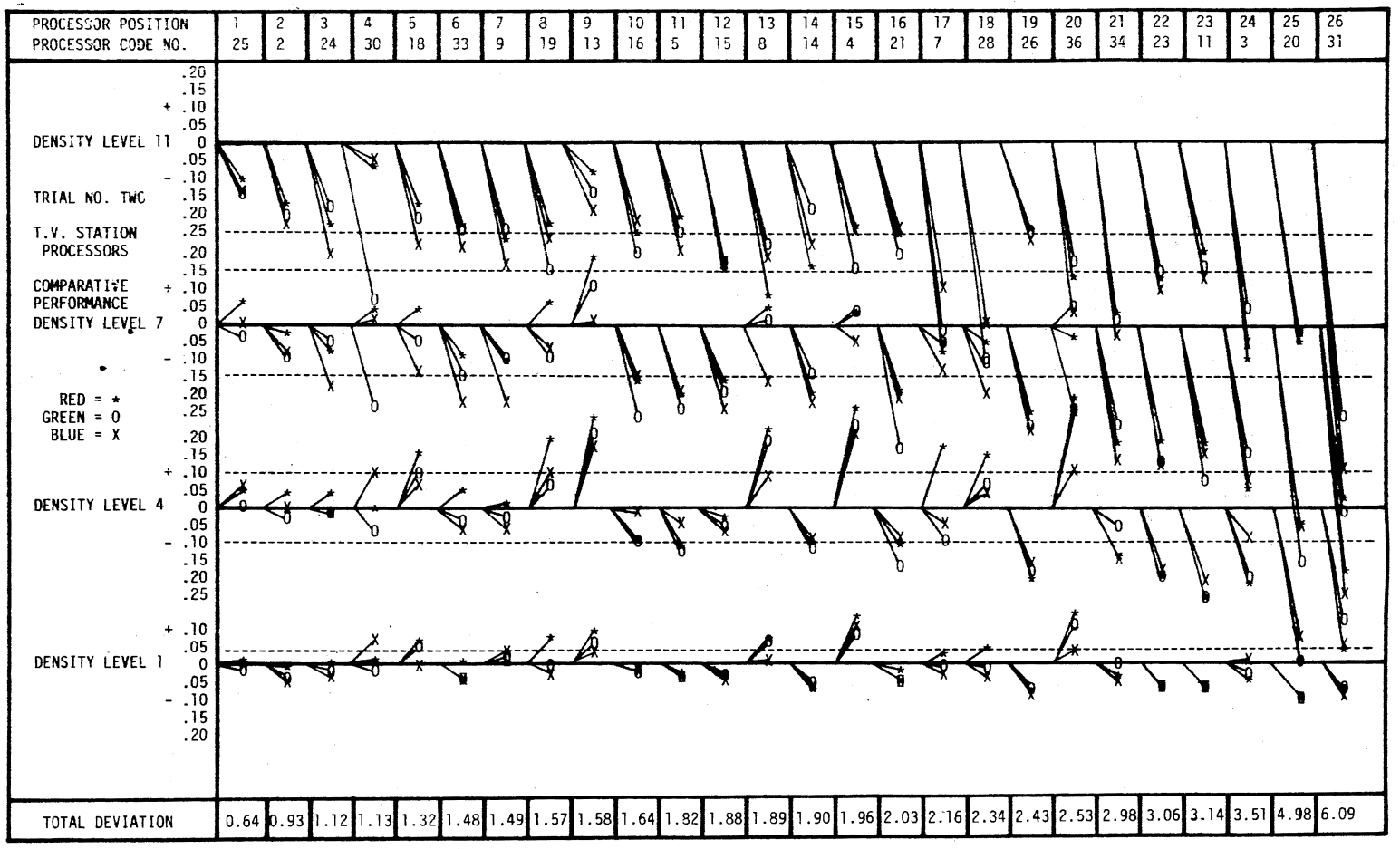

Figure 5. Film Laboratory Processor Comparative Performance Chart, Trial One

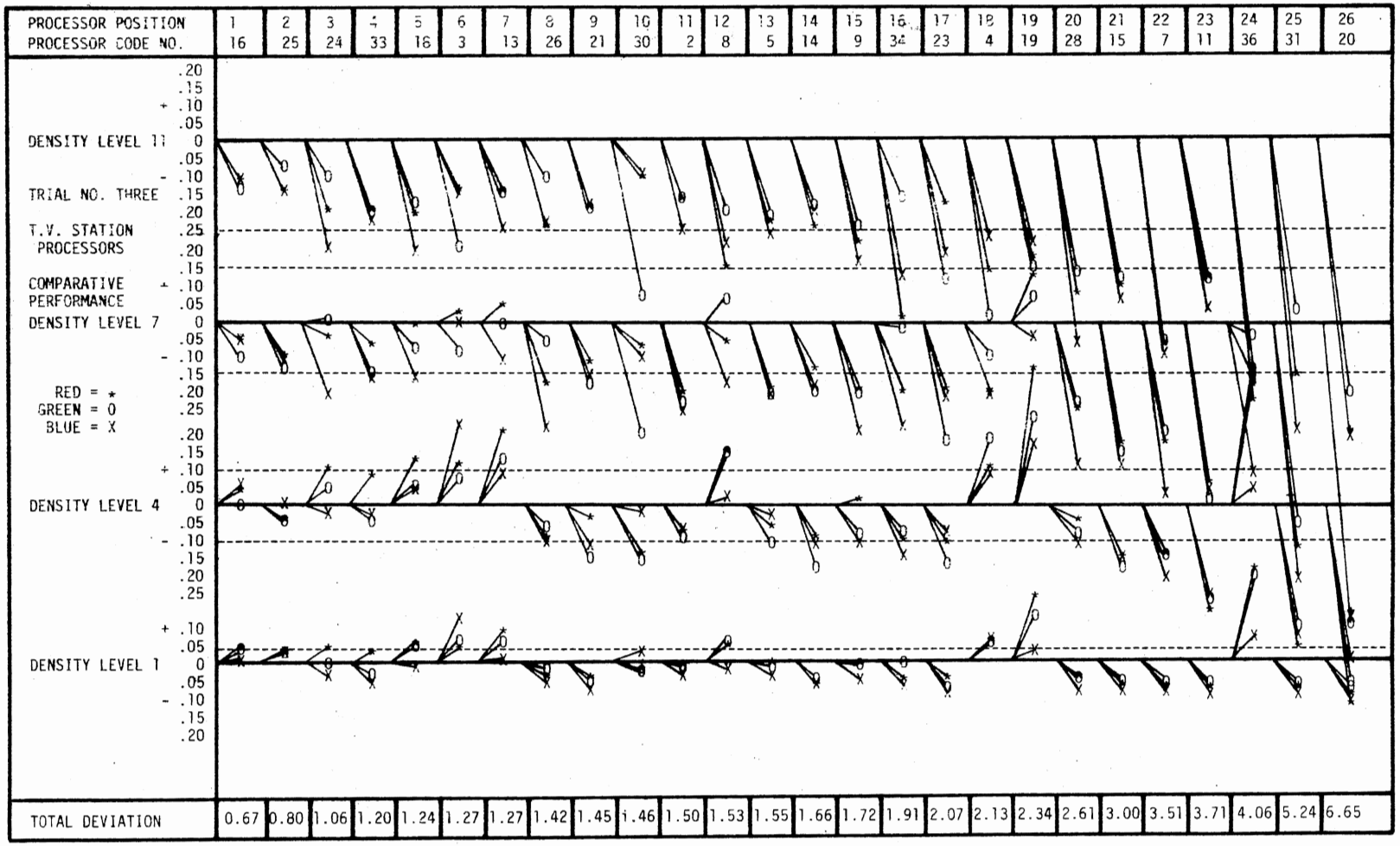

Figure 6. Television Station Processor Comparative Performance Chart, Trial Two

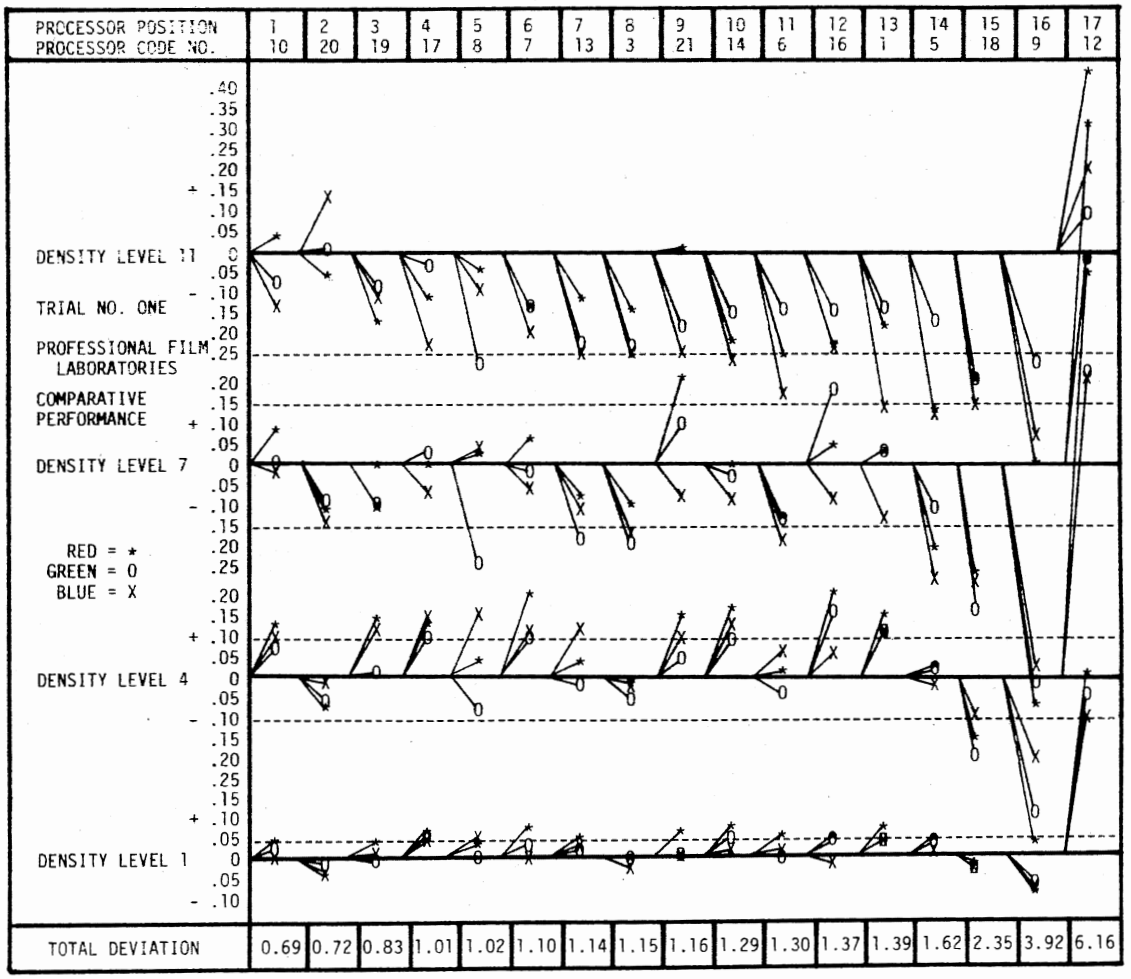

Figure 7. Film Laboratory Processor Comparative Performance Chart, Trial Two

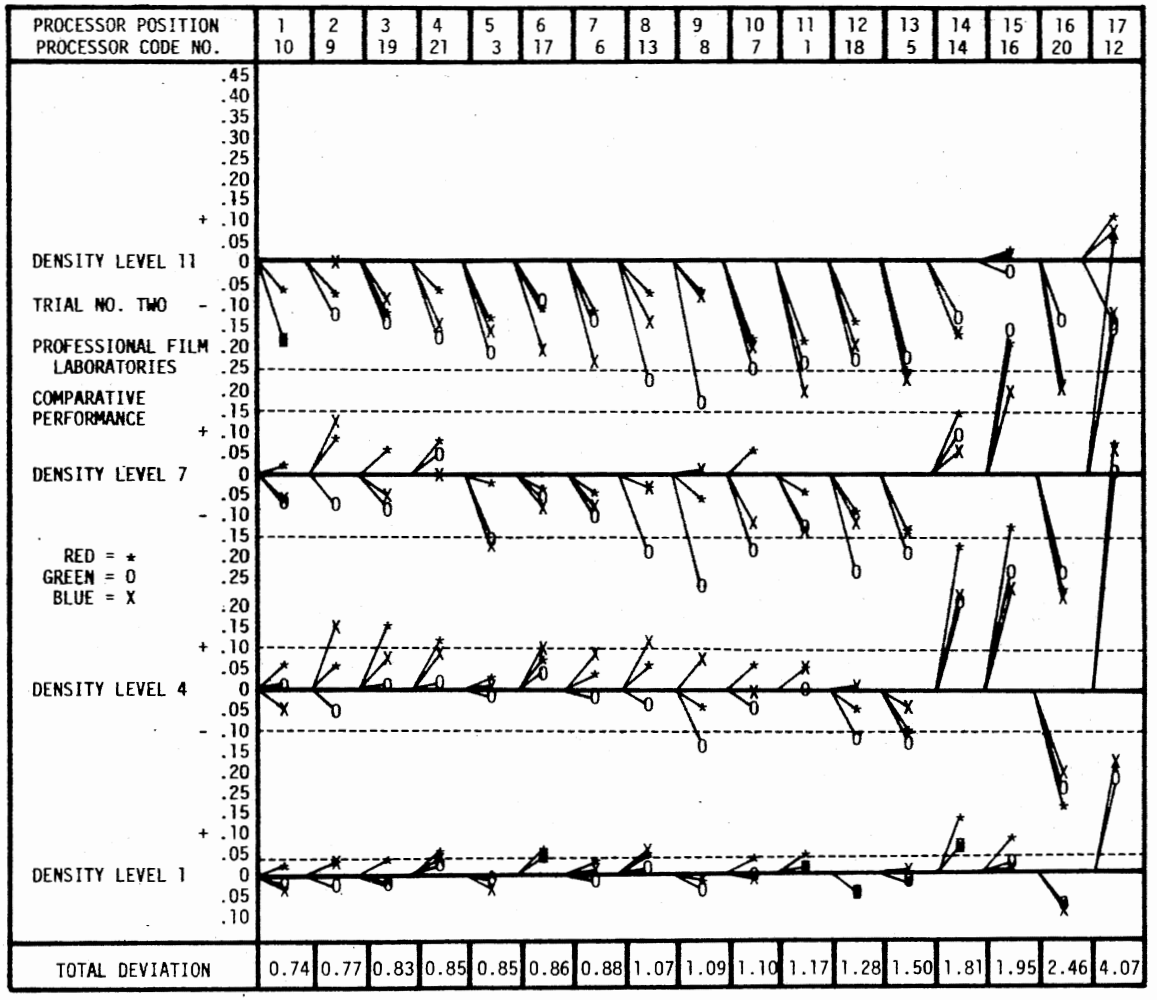

Figure 8. Television Station Processor Comparative Performance Chart, Trial Three

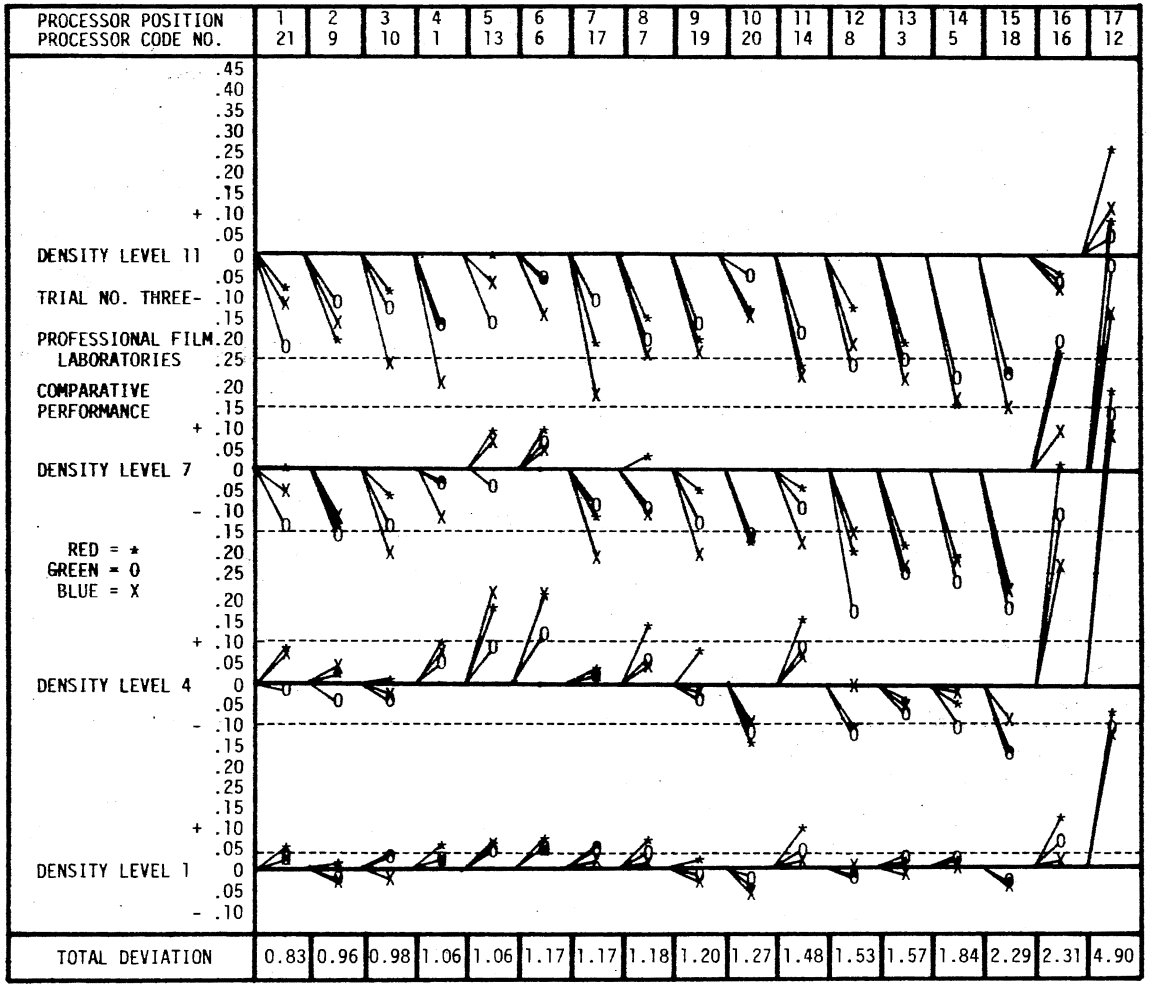

Figure 9. Film Laboratory Processor Comparative Performance Chart, Trial Three

positioning (within .03 density units), they can reflect considerable qualitative information about the processors. The following observations are selected because of their unique characteristics and are presented as examples of important information not readily reflected in the statistical treatment of this study.[5]

Several processors in both groups show densities split above and below standard line. For example, Film Processor 8 (in Trial One) shows a split on Density Levels 4 and 7. The Colors Red and Blue measure +.04 and +.15, respectively, on Density Level 4 and at +.02 and .04 on Density Level 7. The Green, however, plots at -.08 on Density Level 4 and -.24 on Density Level 7. This split of .23 and .26 density units exceeds the manufacturer's color balance standard of a .08 maximum separation on Density Level 4, and .13 maximum separation on Density Level 7 (1). This split resulted in densities which appeared to be closer together, on a simple deviation basis, than they really were. But more important, it also resulted in processed film that was visually biased toward the Green end of the color spectrum. While the color balance of this sample strip is poor, it indicates a reasonably good overall density and places the processor in fifth, out of 17 positions in Trial One. The control strip densities also indicate a probable pH problem in the color developer stage of the processing system.[6]

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[5]The qualitative and interpretive analysis of each participant in this study from graphic illustration is beyond the scope of this study. The data and graphic illustrations supplied in this chapter and in Appendix F are included for concise data information and the reader's benefit.

[6]While mention is made here of a processor problem indicated by control strip color/density characteristics, the discussion of densitometric indication of processor variation and remedy for such variation is beyond the scope of this study.

Conversely, Television Processor 11 positioned poorly in all three Trials. However, the maximum number of density units between any two color critical measurements was .11. While the control strip appeared visually light, the color balance was good and appeared to the eye to be a simple case of over-exposure (Figure 17, Appendix F).

The sample cases, in this study, included examples of both over- and under-processing. Television Processors 20 and 31 registered the lowest overall densities in the study, sharing the 25th and 26th position among the Television Processor group on all three Trials. Television Processor 31 recorded the most significant deviation in the study with a -1.03 on Color Red/Density Level 11 on the second Trial (Figure 32, Appendix F). In contrast, Film Laboratory Processor 12 consistently recorded the highest densities over all three Trials. The highest of these was a +.99 on Color Red/Density Level 4 on the first Trial (Figure 44, Appendix F). This excessive density was equal to several F-stops. A close physical investigation of the three Trial control strips from this processor revealed the processing to be somewhat incomplete, retaining some undeveloped emulsion and thus, accounting for the excessive densities.

Another case of extreme negative direction in density was recorded by Film Laboratory Processor 9 on Trial One. These were the lowest densities recorded by a Film Laboratory Processor in the study; but this extreme was not repeated in later Trials. This same processor (FLP-9) placed second in both the second and third Trials. The contrast in these performances gives rise to the possibility that the first Trial control strip was processed under altered temperature or machine speed conditions (Figure 42, Appendix F).

While the statistical analysis of the study shows that both processor groups are consistent as groups, there are instances of inconsistency across the three Trials. Television Processors 3 and 34 show similar oscillation between the Trials with low densities on Trials One and Two, but with higher densities on Trial Three. Television Processors 15, 20, and 30 (along with Film Laboratory Processor 16) show an inconsistency in their processing that is progressive in the same direction. While the trend of the three Television Processors is toward thinner (decreasing) densities, Film Laboratory Processor 16 shows an increase in density with each successive trial.

The most serious case of inconsistency across the three Trials came from Television Processor 36. The inconsistency of this subject was not related to differences across Trials or in terms of densitometric scores. The inconsistency here was in terms of density direction within the four Density Levels. While the simple deviation placed this subject 23rd, 20th, and 24th, respectively, in the three Trials, the visual quality of the sample control strip was considered the poorest in the study. Density Levels 1 and 4 recorded measurements severely above the standard line with a wider color balance separation. Density Levels 7 and 11 plotted far below their respective standard lines, also with a considerable color balance separation. The range of the plotting chart became insufficient as the density measurements from Levels 4, 7, and 11 all converged into the plotting area for Density Level 7, making the graphic display somewhat confusing. The overall visual quality of the sample control strip was thin. It was dark in the lower Density Levels and had a very Blue appearance. This color characteristic easily can be

distinguished on the chart by the low comparative position of the Color Blue in Density Levels 4 and 7 (Figure 35, Appendix F).

An observation was made of the frequency with which the processing plots exceeded the manufacturer's out-of-control standards. For the reader's convenience, the out-of-control standards are indicated on each chart by horizontal dotted lines for each Density Level. One can observe, from these Trial charts, each instance in which the control limits were exceeded. According to the manufacturer's standard, density readings exceeding these limits is an indicator of a processing system out of control (1).

Table IX shows the percentage of instances in which these control limits were exceeded in a given density, as well as an overall comparison of Television Station to Film Laboratory Processors.

TABLE IX

PERCENTAGE OF INSTANCES EXCEEDING MANUFACTURER'S OUT-OF-CONTROL STANDARDS

Density Levels	Trial No. 1		Trial No. 2		Trial No. 3		Mean Percentages
	TVP	FLP	TVP	FLP	TVP	FLP	
11	55%	24%	68%	14%	51%	24%	39.33%
7	55%	35%	54%	37%	51%	43%	45.83%
4	49%	49%	47%	37%	50%	35%	44.50%
1	19%	35%	18%	27%	22%	35%	26.00%
Mean Percentages	44.50%	35.75%	46.75%	28.75%	43.50%	34.25%	

It is clear from Table IX that the fewest instances exceeding out-of-control standards occurred in Density Level 1. It is also clear that Film Laboratory Processors exceeded the Density Level 1 standard more frequently on all three Trials than did the Television Processors. However, on Density Levels 4, 7, and 11, the Television Processors showed a percentage of instances equal to or exceeding those of the Film Laboratory Processors.

The highest and lowest instances were recorded in the same Trial and on the same Density Level. Television Station Processors exceeded the out-of-control standard in 68 percent of the recorded instances while the Film Laboratory Processors exceeded the out-of-control standard in only 14 percent of the recorded instances.

Looking at all processors as a single group, instances exceeding the out-of-control standard occurred most on Density Level 7, with 45.83 percent. The least number of instances exceeding the standard were recorded on Density Level 1 with only 26 percent. On all three Trials, however, Television Station Processors showed a greater percentage of measurements exceeding the out-of-control standard than did the Film Laboratory Processor group.

When observed on all Density Levels, Television Station Processors deviated beyond the out-of-control limits in 44.92 percent of the recorded instances, while Film Laboratory Processors exceeded the same limits in only 32.92 percent of the recorded instances.

Conversely, an accounting was made of processors from both groups in which there was no instance of exceeding the out-of-control standard. Table X illustrates, by Trial and type of Processor, the study

participants that processed sample control strips completely within the recommended limits of control as specified by the film manufacturer.

TABLE X

PROCESSORS NOT EXCEEDING THE MANUFACTURER'S RECOMMENDED CONTROL LIMITS

	Trial One	Trial Two	Trial Three
Television Stations	TVP-25	TVP-2	TVP-16
		TVP-25	TVP-25
			TVP-33
Film Laboratories	FLP-20	FLP-3	FLP-9
		FLP-6	
		FLP-10	

Of the 43 participating processors, only one (TVP-25) completed all three Trials without exceeding the out-of-control standards, as defined by the film manufacturer.

Summary

This chapter has presented the findings and analyses of the densitometric data retrieved from control strips processed by Television Station and Professional Film Laboratory processing systems. The findings have revealed a basic performance consistency from Trial to Trial, with a fundamental inconsistency from Processor to Processor. In addition,

a qualitative observation has been presented relating to isolated instances of interest as revealed visually through graphic analysis. The following chapter will present a summary, conclusions, and recommendations for further investigation, based on the findings.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this research was to collect and compare densitometric data from Commercial Television Stations and Professional Film Laboratory processing operations with reference to processing consistency of Color and Density across three Trials as measured against the film manufacturer's standard.

To conduct this research, the author posed two questions:

1. What are the relationships between various Television Station Processors and processing quality as measured by Density and Color characteristics?
2. What are the relationships between processing quality and consistency of Television Stations, in general, as compared to the processing quality and consistency of Professional Film Laboratories?

The sample for this study included 26 Television Stations and 17 Professional Film Laboratories from various parts of the United States and the District of Columbia. Each participant processed three VNF-1 control strips six to nine weeks apart to establish a long term interval of consistency. Analysis of the control strips was made using an electronic digital densitometer with status A filters. Reading were made

in multiple and averaged on Density Levels 1, 4, 7, and 11, in keeping with the standard practice of the industry (1). The reading procedure was standardized and methodically conducted to insure measurement and accuracy.

In addition to the main objectives of this study, two additional tests were conducted to determine variation in density caused by mail service practices and environmental influences. Densitometric analysis revealed that mail handling practices of all Trial One samples had no effect upon Color and Density characteristics of the processed control strips, and that all variations recorded could be directly attributed to processing variables. There were no mail test samples sent out for Trials Two and Three.

The latent image shift test, however, recorded a slight density increase in one of the three experimental treatments. While the influence of the treatment to that sample did not result in densities beyond the normal limits of processing, it did establish a slight film emulsion sensitivity to that treatment and a chance that environmental factors may have contributed to some of the unexplained variance observed in the study.

In the statistical analysis, both groups showed an overall deviation from the company standard that was significant at the .05 level. The Film Laboratory Processors deviated significantly on 95 percent of their tasks while the Television Station Processors deviated significantly on all tasks.

In terms of processing consistency, between-subjects F-ratios revealed the processors to be highly consistent from Trial-to-Trial with probability levels falling at the $< .01$ level in nearly every case. A

clearer picture of consistency was shown by the reliability coefficients which reflected the percentage of variation attributable to processor handling across the three Trials. The reliability coefficients indicated that Television Stations tended to be more consistent in the higher densities while Film Laboratories were more consistent in the lower densities.

A rotated Type VI analysis of variance statistical design showed the only significant pattern in the relationships between Processors, Density, Color, and Trials was an increase in observed deviation from the company standard with each increasing Density Level. This held true for both groups.

Qualitative observations showed individual processor variance characteristics, inconsistencies, and extremes that were not apparent in the statistical analyses of the Processors as groups. These observations also revealed a high frequency of processor practice that exceeded out-of-control standards as defined by the film manufacturer.

Conclusions

The conclusions of this study are based on the statistical analysis and quantitative observations as described in Chapter IV. Because of the self-selective sample cases in this study, conclusions presented herein are confined principally to those processors who participated in the study. The reader should, however, keep in mind that all of the Television Station and Film Laboratory processors are currently operating on the commercial market and viewed as practicing professionals by their respective industries on a nationwide scale.

The statistical treatment used in this study was specifically selected to accommodate the variables and answer the two primary questions posed by the author. The first of these questions dealt specifically with the relationships between various Television Station Processors and the quality of their processed film as measured by Density and Color characteristics. This researcher has concluded from the data that Television Station Processors, on the average, depart routinely and significantly from the company standard at all density levels of the processed film. Moreover, there are significant differences between processors in terms of the quality of their film. F-ratios and reliability coefficients also support a considerable degree of consistency in favor of the Television Station Processors (as a group) across the three Trials. This consistency characteristic, in general, means that a given Television Station Processor tends to perform consistently to his own established standards and usually can be depended upon to provide a processing service that is consistent from week to week regardless of its quality.

The second question sought to identify the relationships between the processing quality and consistency of Television Stations in general, as compared to the processing quality and consistency of Professional Film Laboratories. In the overall view it was apparent that the Professional Film Laboratory Processors, like the Television Station Processors, deviated significantly in all Colors, in all Density Levels across all Trials. This implies that the average Professional Film Laboratory is processing film for customers that has departed significantly from the standard recommended by the manufacturer. This overall

deviation, however, was somewhat less in magnitude than the deviations recorded by the Television Station Processors.

In terms of consistency, the Film Laboratories were equally consistent in their processing of film over an extended period. Television Station Processors tended to be more consistent in the higher Density Levels, while Film Laboratory Processors were more consistent in the lower Density Levels. In general, Television Station Processors and Film Laboratory Processors (as groups) were similar in quality and consistency, with the Film Laboratory Processors being slightly more conservative in their departure from the company standard. In addition, both groups tended to register greater departure from the standard with increasing Density Levels.

When observing the individual performance of the processors, both visually and densitometrically, it quickly becomes apparent that there exists both very good and very poor processing operations in each group which persists as a matter of established practice. From the data available, it has been calculated that 38.92 percent of the measurements recorded and plotted for this research fall beyond the film manufacturer's standard for out-of-control process. It was established that, during the three Trials, no more than three processors from each group maintained densitometric readings within the guidelines of the out-of-control standard on any given Trial. Moreover, only one of the 43 participants completed all three trials without exceeding the out-of-control standards. The author, thus, concludes that the normal practice of film processing at Commercial Television Stations and at Professional Film Laboratories is, more often than not, routinely conducted in a

posture that is, at some point in the densitometric range, outside the limits of process control, as defined by the film manufacturer.

Recommendations

The established variation and consistency patterns observed in this research study leads the author to believe that there is a genuine case for universal concern about the overall quality of processed VNF motion picture film. The economics and news reporting styles of our time are continuing to make their impact on the film related industries and it is apparent that the observed quality of film processing is not in the best interest of the users, or the industry in general. The following recommendations are based on the data and experiences derived from this research.

Recommendations for Further Research

While there is considerable literature that is addressed to various segments of film processing, there has been little effort to draw comparisons on the processing industry in general. This study has attempted to supply some evidence in this direction. However, there is much to be learned through further research. The author, therefore, recommends the following procedures for conducting research relative to consistency and quality film processing:

1. A replication of this study with a larger sample.
2. A replication of this study with a greater number of trials.
3. A study of similar design conducted in close cooperation with the film manufacturer using the manufacturer's processing facilities as the standard for performance.

4. A study of Film Laboratories only comparing performances on various types of film stock.
5. A study comparing high volume and low volume Television Station processors.
6. A replication of this study conducted in an area of the United States with a sizeable sample of local Television Stations for purposes of increasing the number of Trials and shortening the time period between Trials.
7. A more conclusive latent image shift analysis.

Recommendations to the Industry

The quality and consistency of any given Film Processor is established by daily philosophical practices and is likely to improve only through the efforts of strict chemical and densitometric monitoring procedures. This is contingent upon the sensitivity of the processor operator to his product. Since a variable sensitivity to product quality is in evidence, it might be advisable for the processor manufacturing industry ot develop automatic sensing devices that would detect and correct variables that are critical to film processing quality. These innovations should be adaptable to existing machines and tied into displays for the monitoring of each selected segment of the system. These measures then should be reinforced by densitometric analysis.

Another valuable innovation for process control would be the development of a special high contrast emulsion that is sensitive only to the range of proper processing conditions. This would aid the processor operator in terms of a "quick glance" reference. This type of process monitoring strip would be introduced to the processing machine in the

same way the standard control strips are handled but would supply only visual data with reference to chemistry and temperatures. Conditions which exceed the control standards could be easily observed by visual cues from the monitoring strip. This would also be a desirable control measure for Television Station Processors who are not equipped with a densitometer.

It is the responsibility of the processors themselves to take advantage of tools available for controlling their own individual operations. While this, at times, can be expensive and inconvenient it is still the only single variable that ultimately can determine a high quality processing operation. No process can maintain acceptable standards if the immediate priorities are placed elsewhere.

Finally, the customer, whether a news cinematographer or independent film producer, must resort to the tried and true method of knowing his processor. This research has shown that, regardless of the size of the processing operation, the likelihood of handing over exposed film to a quality processing operation, as defined by the film manufacturer's standard, is no better than chance. It is, therefore, highly recommended that a sample roll of known exposure be submitted and checked after processing for both visual and physical quality.

It is the hope of this author that the reader has acquired a better perspective of the quality of film processing, as it relates to the two groups of participants observed. It is also hoped that the information shared herein will benefit the industry, in general, and that an awareness to the real and now tested conditions that exist throughout the industry will show some measure of improvement in the years that follow this research.

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APPENDIXES

APPENDIX A

VNF-1 PROCESSING

All Ektachrome film stocks intended for process VFN-1 are processed in continuous strip form. Individual rolls of exposed film are connected end-to-end, using an acceptable secure splicing procedure and then fed into the machine without influencing film already in the processing cycle.

The film, when run through the various stages of the processing machine, is transported through the solution tanks, emulsion side up, on a series of mechanically driven spools. The spools are mounted in removable racks that fit into the tanks (rack and tank system), with the film threaded over the spools so that film travel takes place in a continuous spiral path on each rack. The size of the rack, the number of spools, and the speed of the machine, determine the amount of time that the film is subjected to a given stage of the process. At no time, should any part of the image area be allowed to come in contact with any part of the machine that will cause damage to either the support or the emulsion side of the film.

It is important that squeegees be located in strategic positions to minimize carry-over of solutions from tank to tank. Careful attention should be given to the condition of the squeegees as they age. If they become worn or develop crystalized or foreign material, it can result in contamination of the succeeding step in the process and scratching of the emulsion side of the film.

The materials of which the processing machine is composed, for the most part, is fixed by the manufacturer. An exception to this is the machine that has been custom-built to the physical specifications of the processing service management. The recommended materials for film processing are outlined by the film manufacturer. They recommend the

tanks and racks be composed of stainless steel, AISI Type 316, except for the bleach tank. The bleach tanks and racks should be constructed of alloys that are composed of at least 85 percent copper. Hastelloy C and titanium are also acceptable. Materials other than those recommended may be used only if they are lined with an inert material such as hard rubber, rigid polyvinylchloride, fiberglass reinforced polyester or epoxy-filled coatings. The fiberglass reinforced plastics should not be used for the color developer tank.

Black iron is a suitable piping material for the first developer and color developer. Copper is appropriate for wash water lines. Stainless steel, AISI Type 316, should be used for fixer lines in VNF-1 processing. If the machine is to be used for ME-4 process, the first two steps, pre-hardener and neutralizer, should also be equipped with stainless steel lines. Bleach lines should be composed of polyvinylchloride that is resistant to bleach corrosion. Flowmeters and valves for the bleach should also be composed of polyvinylchloride. Nylon valves are also acceptable.

Processing Steps for VNF-1 Process

(Abbreviated)

A. First Developer: Develops exposed silver halide to a black and white negative silver image.

B. First Stop: Stops the action of first developer carried over by the film; also reduces the emulsion swelling during the next wash.

C. Wash: Removes the acid solution from the film.

D. Color Developer: Contains a reversal agent that sensitizes the remaining silver halide in the film, thus eliminating the necessity for

re-exposre by light. Develops the sensitized silver halide to give positive dye images and silver images in the appropriate emulsion layers of the film.

E. Second Stop: Stops the action of the color developer carried over by the film and reduces emulsion swelling.

F. Wash: Removes the acid solution from the film.

G. Bleach: Converts all metallic silver to insoluble silver salts.

H. Fixer: Converts all silver salts to soluble compounds and removes them from the film.

I. Wash: Washes fixer from the film.

J. Stabilizer: Hardens the emulsion and stabilizes the dry images.

K. Dryer: Dries the film for windup and subsequent printing or projection (1).

Like other composite color film stocks, Ektachrome Video News Film stock is composed of several layers of light sensitive emulsions. The processing operation must simultaneously control the various chemical reactions that take place in each of these layers. In addition to these reactions, it is important that interference of one reaction with another be kept to a minimum, or at least held to a constant. Most important, the reactions must be allowed to proceed to a point of pre-determination and then held consistently at that point where the proper contrast relationships, minimum and maximum densities, permissible to fog and stain levels, and the correct color balance are obtained in the film when the processing operation is completed.

A deviation from specified processing conditions involving the four factors--time, temperature, agitation, and chemistry--will not generally affect all layers in the same way. It is fundamentally unsafe to make

the assumption that a deviation from one specification can be adjusted or corrected by a compensating modification to another step in the process.

Once conditions in the processing have been established, which conform to optimum standards for a given emulsion, there is little opportunity left for the modification of the process. In order to maintain this optimum standard, specialized equipment and procedures must be incorporated into the normal processing routine if consistent high quality results are to be maintained.

To maintain proper process control, a procedure of continuous photographic and chemistry evaluation must be methodically conducted at regular intervals. Whenever changes do occur, a procedure for diagnosing the difficulty and locating the cause must be available. Corrective action must then be taken to restore the process to its original condition.

In order to establish a complete process evaluation system, consideration must be given to three specific control variables:

1. The measurement and regulation of mechanical specifications (processing machine).
2. The analysis of processing chemistry.
3. The conducting of sensitometric tests to establish chemical and mechanical relationships with photographic results (3).

Mechanical Control

Machine speed (solution time), solution temperatures, replenisher flow rates, and recirculation rates are the variables which actively influence the chemical activity that takes place during the processing

operation. Their consistency is fundamental to maintaining photographic consistency.

The processing machine is usually equipped with a tachometer calibrated in feet per minute. It is recommended that the speed be checked daily. When forced processing has been conducted, it is recommended that the machine speed be checked after normal speed is resumed.

The machine speed can be visually checked by splicing markers into the leader and measuring the time of the mark in each solution with a stop watch. Adjustments to machine speed should be adjusted to keep the times within $\pm$ 2 percent of the recommended time (3).

The temperature of the various solutions should be checked hourly. It is important that an accurate thermometer be used for solution temperatures in that serious out-of-tolerance conditions can exist within a few degrees. While all stages of the process are temperature sensitive, the most critical step in any process is the first developer. For the VFN-1 process, the required temperature of the first developer is 100 degrees $\pm$ 0.5°.

Replenisher flow rates should be checked at the indicator every two hours. The indicator should be calibrated once a month by a 500ml graduated cylinder and a stopwatch. This is accomplished by tapping into the replenishment line at a convenient place. If an out-of-tolerance condition is discovered, the calibration mark should be adjusted and the test repeated (1) (3).

Air agitation and recirculation systems should be checked every two hours and fluid control squeegees should be checked periodically for proper operation, alignment, and cleanliness. Filters should be changed weekly or bi-weekly and should not be allowed to become clogged.

All critical checks and adjustments can be routinely accomplished through strict adherence to a carefully prepared checklist.

Chemical Control

When formula packaged chemicals are used in recommended quantities, the various stages of the process are considered to be within safe chemical limits as stated by the chemical manufacturers. Bulk chemicals must be mixed to required specifications.

The most critical chemical variable in process VNF-1, as in other color film processes, is in the color developer. The single most important influence on photographic color characteristics of processed color film is the pH level of the color developer. The manufactuer's specification for the pH level of the color developer tank chemicals is fixed at 11.65 $\pm$ 0.10 at 80°F. If the pH level is allowed to rise above specification, the reaction will produce an excessive amount of yellow dye and an insufficient amount of magenta dye, resulting in visual color characteristics of a green-yellow appearance. If the reverse trend occurs and the pH drops below specifications, an inverse reaction will occur and the film will have a magenta-blue appearance.

While pH characteristics can be adequately maintained by proper replenishment rates and temperature levels, photographic and chemical analysis should be conducted for confidence. The color developer reactions and tendency to absorb carbon dioxide from the air contributes to a lowering of the pH (1). This is augmented by the film's sprocket holes carrying air into the solution (37).

Because of this variable, the replenishing solution is fixed at a

higher pH level (11.98 $\pm$ 0.10 at 80°F), to adjust for this characteristic (1).

Sensitometric Control

The chemical processes involved in the processing of color film are too complex to evaluate by mechanical and chemical data alone. Since the end product of the process is photographic and visual in nature, it stands to reason that a visual analysis of the product would yield the most pertinent data. Visual differences coupled with mechanical and chemical data can result in very accurate indicators for systematic processing controls.

There are two types of visual processing tests that may be used to evaluate film quality. Since the test is visual, a test scene can be composed using a black and white reference, along with color references and Caucasian facial tones. The exposure should be made with a known light level/T-stop combination. Segments of this footage may then be spliced into the processing machine along with the normal work and visually analyzed and compared with previous segments for picture quality and color and/or density differences. These samples can also be analyzed by densitometric tests by making readings on the black and white references; along with color references on flesh tones. A sample-by-sample comparison of densitometric readings will give a good visual interpretation of the photographic product as well as a suggestion of process stability. This test, however, should not be considered as a substitue for a sensitometric test.

Sensitometric process control strips are exposed under highly reliable and standardized conditions and if exposed in a processing

laboratory's own sensitometer, must be standardized to the manufacturer's quality specifications. This may be done by comparing the densitometric readings of the sensitometric control strip to a manufactuer's control strip which is, in turn, compared and plotted against a reference control strip processed by the manufacturer.

Manufacturer's control strips should be handled with the utmost care to avoid potential variance which may improperly indicate processing variation.

Quantitative measurements of sensitometric strips should be made on a quality densitometer equipped with status A filters to measure the integral density of selected steps to red, green, and blue light. Once the densitometer is checked and calibrated, the processed strips (manufacturer's control strips) are measured in density steps one, four, seven, and eleven, through the three primary filters and recorded. The recorded measurements are then compared to the manufacturer's reference strip and the differences are plotted on a chart. These differences represent the processing departure from the manufacturer's recommended standard and, assuming the handling and measurements conform to proper procedure, are representative of conditions that prevail within the processing machine.

Recorded density values of steps one, four, seven, and eleven, are plotted against control limits. The density limit for step one is +0.03 above the zero line. There is no limit below the zero line.

Step four limits are set at $\pm$0.10 about the zero line, $\pm$0.15 about the zero line for step seven, and -0.25 below the zero line for step eleven. Densities exceeding these control limits indicate an out-of-control condition in the processor. While the densities may exceed the

limits, the images of film accompanying the control strip through the processor may not necessarily reflect an unusual quality. The lack of visual difference can be explained if the three color readings of a given density closely coincide in their departure from standard. If the colors do not vary together and a marked spread in one of the colors occurs in density four or seven, an observable difference can be seen in the color characteristics of the control strip and of accompanying pictures. The process is then said to have a color balance problem. This problem exists if a spread of 0.08 occurs between any two colors in density four and 0.13 difference in density seven. If either out-of-control or color balance conditions exist, no further film should be processed through the machine until the problem is isolated and corrected (1).

APPENDIX B

MOTION PICTURE FILM CONSTRUCTION

Film Transport

Motion picture film consists of a durable transparent and flexible material that is coated with a light sensitive emulsion capable of recording a latent image that is converted to a metallic silver image when processed by an established chemical technique. This statement is a description of film stock that is used in the motion picture and the television industries today. Motion picture film stock begins, both in concept and manufacture, with a transparent base material that serves as a carrier for the photosensitive emulsion. Prior to World War II, film base for professional motion pictures was composed of cellulose nitrate and was the same formula as that furnished to Edison. An amateur motion picture stock in a 16mm format was introduced in 1923, by the Eastman Kodak Company, with a base composed of cellulose acetate. Eastman refused to release film to the public with a base composition of nitro cellulose because the film decomposed in storage and the resultant fire risk was similar to that of stored explosives.

Cellulose acetate is manufactured by treating cotton or wood pulp with acetic acid, acetic anhydride, and a catalyst, usually sulfuric acid. An excess of acetic acid is usually present and the ester, cellulose triacetate, which is formed by the reaction, is dissolved in the excess of acetic acid.

A part of the acetyle groups is removed from the cellulose triacetate by hydrolysis and the partially hydrolyzed cellulose acetate is then precipitated by pouring into water. After a thorough washing, the resultant cellulose diacetate is soluable in acetone. A variety of plasticizers has been used in making film supports from cellulose

acetate. These include ethylor butyl phthalate, alpha chlornaphthalene, and triphenyl phosphate. The objective of the plasticizer is to further reduce the fire hazard of the cellulose acetate and the plasticizer is coated onto a large wheel with a highly polished surface. The coating is kept at a constant thickness as the solvents are evaporated. As the polished wheel is slowly turned one full revolution, the clear plastic film is drawn off and passed over a series of heated rollers to remove the remaining solvent. The film is then coated with a substratum usually composed of gelatin and cellulose nitrate, or cellulose acetate, to promote the adhesion of the photographic emulsion during the coating process.

In more recent years, cellulose triacetate has replaced the cellulose diacetate but cellulose triacetate must be dissolved in a solution of methylene chloride which, when rolled onto a transparent sheet, offers highly desirable properties as a base for motion picture film (38).

Gelatin

Gelatin is the binder that holds the light sensitive silver halide crystals in suspension and apart from each other. It, in turn, holds the light sensitive coating to the cellulose acetate film support while allowing penetration by chemicals during the process of development.

Gelatin is composed of a mixture of related chemical compounds of the protein group, with molecules made up of amino acid residues. Photographic gelatin is manufactured from bones and clippings of the skins of cattle and pigs. The clippings are washed and treated with lime for a long period to remove fat and hair. The lime is then removed by a long

washing with a weak acid and then with water. The resultant material is then cooked in steam kettles until the gelatin is extracted, after which it is allowed to set to a jelly. When set, the blocks of jelly are cut into thin slices and dried (39).

All pure gelatin is not suitable for photographic emulsion. In 1923, Dr. Samuel E. Sheppard published the results of a study that he conducted into the various fractions obtained at each step in the preparation of photographic gelatin. In the acid liquors in which the lime clippings had been washed, there appeared to be a concentration of sensitizer. If this liquor was added to a gelatin which did not give sensitivity, it increased the sensitivity of the emulsion.

Sheppard extracted a very small quantity of a fatty substance from the acid liquor and found that when the same fatty substance was prepared in a pure form, it had no sensitizing power. The sensitizer was merely associated with an impurity. A material similar to the fatty substance could be obtained from the seeds of plants which had sensitizing powers particular to the mustard seed. The fatty substance appeared to be of a nature similar to mustard oil which contains sulfur and was presumably acquired by the animal's pasturage. To explain the natural sensitization, the mustard oil (when treated with alkali) breaks down into allyl thiocarbamide and the surface of the silver bromide is attacked and grows a mass of white needles containing both allyl thiocarbamide and silver bromide. If these white needles are treated with alkali, they break down into little black spots that consist of silver sulfide. Sheppard theorized the little black spots or "specks" were probably the sensitivity centers around which the latent image is formed.

Photographic gelatin, as a binder material, is desirable for a number of reasons: (a) when dry, the material is strong and tough, holding the silver halide grains firmly to the film base, protecting them from physical damage; (b) it holds the silver halide grains apart and suspended throughout the emulsion; (c) it provides a convenient medium in which solutions of silver nitrate and alkali halides can be brought together to form crystals of water-insoluble halide. When the crystals are formed in the presence of dissolved gelatin, they are held in a collodial suspension; (d) as an emulsion, when the gelatin is coated onto the film transport, it can be applied in the form of a sol at convenient temperatures and upon cooling, sets to a gel; (e) dry gelatin, when placed in water, swells allowing penetration by processing agents solution; (f) gelatin is stable over long periods of time; (g) it acts both as a sensitizer and a trap or acceptor for freed bromine atoms during the formation of the latent image; (h) it prevents the reduction of unexposed silver bromine crystals by being absorbed to the crystal, thus producing a barrier which greatly retards the action of the developer in the unexposed areas; (i) it is easy to manufacture in bulk form; (j) it serves to regulate the size of the silver halide crystals as they are formed and provides a desirable environment for modifying the crystal size (38).

H. Baines (40) once said about the properties of gelatin for photographic purposes:

> Such a remarkable combination of useful characteristics seems almost more than coincidence and one feels that the Almighty must have created the cow with photography in mind. Perhaps the only improvement which one could suggest would be the inclusion of silver halide in the cow (p. 67).

Once the seasoned gelatin has been prepared, it is ready to be processed into a photographic emulsion. The process of emulsion manufacturing is explained by Dr. O. E. Kenneth Mees (38):

> Emulsions for use in the camera are made by suspending silver bromide in a solution of gelatin. Silver bromide is very insoluble in water, so that if a solution of silver nitrate is added to a solution of potassium bromide, the silver bromide is precipitated. In water solution, it settles to the bottom of the vessel. If, however, gelatin is present in the solution, the silver bromide remains suspended to make an emulsion; therefore, gelatin is soaked in water, and when swollen, it is dissolved by putting it in warm water and gently warming and stirring until all of it is dissolved. Then the proper quantity of potassium bromide is dissolved in the solution. Meanwhile, the appropriate amount of silver nitrate to act with the amount of potassium bromide chosen is weighed and dissolved in water. The gelatin and bromide are held at a very even temperature, usually in a water-jacketed kettle; the inside of the kettle must be made of pure silver. The silver nitrate solution also is held at a fixed temperature and is run in while the mixture is stirred continuously. Then the emulsion is digested for a certain time, partly to allow for different sizes of crystals to come into equilibrium and partly because some changes occur which affect the ultisensitivity of the emulsion. Since the silver bromide is sensitive to light, before the silver nitrate is added to the bromide and gelatin, all the white lights are turned out, and the nitrate is added by the light of a photographic red lamp. When the silver bromide is precipitated, the potassium of the potassium bromide and the nitrate of the silver nitrate, remain in solution. To eliminate the potassium nitrate and any excess of potassium bromide, the emulsion must be washed after having first been set to jelly. This is done by chilling it, and the set jelly, which resembles the familiar blancmange, is shredded, usually by forcing it through the holes in a metal plate at the bottom of a press. The shredded emulsion, which looks much like broken-up macaroni, is washed for several hours in running water until all the soluable salts have been washed away. Then the emulsion is re-heated and the jelly melts. Usually some fresh gelatin is added and a further digestion is given, during which the emulsion increases very markedly in sensitivity. It is then ready to coat in liquid form (pp. 149-150).

The photographic properties of the emulsion depend upon the sensitivity of the different sizes of the crystals produced. In turn, the range of the sizes of the emulsion crystals depend upon the concentration of the

silver nitrate and potassium solutions, the temperature, the type and amount of gelatin present, and on the rate of mixing (38).

APPENDIX C

COLOR IN THE MOTION PICTURE INDUSTRY

More than 50 separate color motion picture processes have evolved since 1900. The emphasis has shifted from additive to subtractive processes and from two color to three color processes. Complicated mechanical and optical devices for photography and projection have been abandoned in favor of standard studio and theater equipment used for black and white motion pictures. It is interesting, however, to reflect upon the early efforts and difficulties involved in bringing color to the projection screen (41).

The production of motion pictures in color did not occur until well into the era of dramatic films. However, there is evidence of the tinting of motion picture film prior to 1900. The first such practices were of a hand-painted variety that attempted to resemble natural color. This gave way to the tinting or toning of various colors.

In the 1920's, the popular trend ended with the introduction of sound. The dyes used in the tinting process absorbed valuable light frequencies and tinting, being the least important of the two, was discontinued in favor of the "talkies." This was the case until the Eastman Kodak Company introduced a colored film support suitable for sound or silent motion pictures.

Additive color techniques were in existence before 1900 and have been in existence up through the late 1950's. However, for the most part, the additive process of projecting color films was unsuccessful as a commercial enterprise.

The first feature film in color was made in England and was entitled "The Glorious Adventure." The problems of early color involved the registration of the colors since a "color film" had not yet been invented.

The technique consisted of projecting two specially exposed black and white images through their respective color filters. They then were registered together on the screen. In the early days, the two-color system consisted of red and green with the third color blue being technically too complicated to be included.

"The Glorious Adventure" was produced in Kinemacolor, which was a technique incorporating successive pictures taken first green, then red. When projected rapidly, the colors registered nicely, unless there was a quick movement in the action. The colors would then separate, producing horses with two tails, one green and one red, a problem commonly known in the industry as "fringing."

The earliest perfect registration of a two-color technique was developed by the Technicolor Corporation. Their first feature film was called "The Gulf Between," which began filming in January of 1917. The first Technicolor Laboratory was built within a modified railway car and could be transported great distances along the rail lines. It was completely outfitted to process both the negative and positive prints, in addition to making all necessary inspections and tests.

The Technicolor design called for a special camera using a standard film design and incorporating a single lens, beam splitter, and two photographic components--one for green and one for red. The color composite images in this design were filmed simultaneously. When projected with a double aperture, the two pictures were registered with no color fringes visible unless something mechanical happened to the adjustment device. Maladjustment occurred frequently and eventually caused Technicolor to abandon this additive process of color projection (11).

In 1924, J. H. Prowie invented the Warner-Prowie Color Process, a three-color additive system. The technique involved a structure of 900 lines to the inch, running lengthwise on the film. The film ran horizontally through the camera and exposed through the base side of the film. The film required a special type optical printer and a complicated image shifting technique to create the three separate colors.

In the late 1920's, C. Roy Hunter, of Universal Pictures, patented the Magnachrome Film Process. This was a two color system which used a conventional camera. The film used was a bi-pack system (two films back-to-back) and in printing, each normal sized frame contained two half sized pictures (one from each negative record). It projected at twice the normal speed to compensate for sequential frame color problems (41).

During this same decade, the Technicolor Coporation experimented with a subtractive technique by printing two component negatives on a special thin print film (gelatin on celluloid), to which a dye was added to the component prints. The green and red dyed prints were then cemented back-to-back, to compose a single ribbon of film that could be projected with one lamp. This design posed serious problems with the prints during projection. There was a color fringe problem due to registration difficulties which not only made both colors visible, but degraded the sharpness of the picture. The film was thicker than conventional black and white film and would cup randomly in either direction as it ran through the gate, due to the presence of emulsion on both sides. This caused the film to scratch easily and jump in and out of focus. Technicolor conceded that this modified imbibition technique was only temporary and that a true imbibition process incorporating

a single ribbon would have to be developed. Because of these problems, producers of motion pictures were less inclined to invest in color film productions until a more reliable and economical system could be devised.

In 1928, Technicolor introduced a two-color imbibition print on a single base with a silver sound track for better audio clarity. The innovation was an instant success. An added value to this product was an even harder, scratch-resistant emulsion than that used in the standard black and white film.

But Technicolor's problems were not completely solved. While the two-color process was the best available, management was aware of the possibility that the public would soon tire of the unrealistic color renditions and the demand from the producers would quickly evaporate. Therefore, in May of 1932, Technicolor completed the building of its first three component cameras (11).

The camera simultaneously exposed three negatives at one time. The red and blue filtered images were placed face-to-face while the green filtered image was supplied light by means of a prismatic beam splitter. The three negatives then were printed on a special matrix stock. The silver in the images was used to harden the gelatin of the matrix emulsion so that after they were washed, relief images remained in the gelatin. The three component images were then dyed their respective colors and transferred to an ordinary positive blank film by the complex process called "imbibition" (38).

In this process, each of the three independent colors were transferred to the blank film upon which the silver image soundtrack had already been developed. The technique involved bringing the dyed matrix into intimate contact with the blank under multiple roller pressure in

the presence of heat which transferred the dye from the matrix film to the blank film, one color at a time. The system allowed for film shrinkage to perfectly register each color during the dye transfer. After the third color had been transferred, the blank, now a composite print, was dried and rolled on a reel. A new blank was introduced to the imbibition printing machine and the process was repeated using the same three matrix transfer prints (42).

From this immensely complicated technique came such milestones in motion picture history as "Gone With The Wind," "The Wizard of Oz," and several Walt Disney full-length cartoon features among others.

Cosmocolor was introduced in the late '30s as a two-color additive process using block prism projector optics, but was converted to a subtractive process before commercial use. Later on, a third color was added.

Since 1936, Telco color, Thomas color, and Colorvision, all additive color systems at their inception, were either converted to subtractive color systems before commercial introduction or bankrupt before realizing any real success.

The subtractive color process was much more successful than the additive color. Instead of projecting the various colors simultaneously, as in the additive color technique, the subtractive technique subtracts the light that strikes the film and the screen receives only what is left, the colored image. This essentially eliminates registration problems and extraneous projection equipment.

In 1913, J. G. Capstaff invented the Kodachrome process for still photography and the technique was later expanded to include motion pictures. In 1931, a process called Multicolor was introduced as a two

color subtractive process. Multicolor's rise to popularity was timed to the economic depression and soon went bankrupt. In 1946, Consolidated Film Industries announced the Trucolor, a two-color subtractive system, and later, in 1949, as a three-color system.

The key to a successful and lasting color process was apparent in the perfecting of a single base, multilayer color film. In the late 1930's and early 1940's, Dr. Bela Gaspar brought the Gasparcolor process to Hollywood. The Gasparcolor technique featured color sensitive emulsions on both sides of the film support. The technique was not used beyond commercial color cartoons.

The Kodachrome Commercial Safety Film was introduced in 1946 and was designed as a low cost original intended for printing. It was a multilayered reversal film that was eventually replaced by the Ektachrome Commercial Film in the 16mm format.

In the early 1950's, both the Eastman Kodak Company and General Aniline and Film Company introduced multilayer negative films involving three light sensitive emulsions on a single film support. Each of the emulsion layers incorporated dye couplers that reacted during a single development to produce a separate negative dye image in each layer, complementary in color to the sensitivity of that layer. Each company also produced a companion print film of similar design.

These film stocks are essentially the type of color negative camera films used in the industry today and derivatives of the Ektachrome reversal film stocks discussed earlier are the type used for news filming and documentaries (40).

Since the days of color prints from black and white original, film "speeds" have increased dramatically and with this increase, has come a

reduction in set lighting levels and a more dramatic and interesting use of lighting. Color quality and uniformity have been improved substantially and, because of these improvements, the "natural color" processing of today produces a much truer reproduction of the scene that is photographed. New techniques in film manufacturing have produced emulsions having extremely fine grain structure and excellent definition (42).

APPENDIX D

LIGHT SENSITIVITY AND LATENT IMAGE THEORIES

While the behavior of light upon a sensitized surface has been experimentally observed for hundreds of years through the photographic process, it is not fully understood, nor can it be described in terms of what actually happens. There are, however, predictable characteristics exhibited by substances which make up the sensitized emulsions of the various films and the chemical behavior of these materials has given rise to theories which explain the latent image phenomenon.

In 1917, M. B. Hodgson placed a small amount of emulsion, to which he added a weak developer, under a microscope. He then observed the process of development. He noticed that the development formed around definite specks in the grains of the emulsion. The specks continued to develop until the grains were transformed from their original crystalline shapes into a mass of metallic silver.

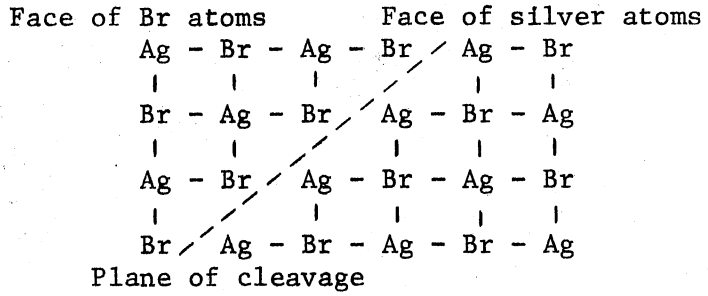
Dr. Samuel E. Sheppard suggested that the sensitivity of silver bromide grains is dependent upon the existence of specks that might consist of silver sulphide, and that the specks act as gathering centers for material produced by the action of light. Sheppard advanced the Concentration Speck Theory to explain the phenomenon of the latent image. He envisioned the specks of silver or silver sulfide to be formed on the surface of the silver bromide crystal and that they must enter into the crystal through the lattice of the atomic structure. He felt that the presence of the specks put a strain upon the crystal thus creating an area of weakness. Sheppard then theorized that when light struck a weakened crystal of this type, electric charges were transferred through the crystal, where they reached the boundary of the speck and at this point, metallic silver was released, thus fixing the location of the latent image.

In 1930, Sheppard's theory was supported in part by Dr. J. H. Webb of the Kodak Corporation Research Laboratories and later, by two professors from the University of Bristol, R. W. Gurney and N. F. Mott. They agreed with Sheppard that, when light is absorbed by the silver bromide grain, it liberates electric charges, but Gurney and Mott, through methods of quantum mechanics, suggested that electrons could move readily through nearly perfect crystalline lattices over thousands of atomic distances without interference until they became caught in traps in the form of lattice imperfections or foreign atom impurities. They may be the specks that Sheppard observed (38). To better understand this theory, it is important to understand the physical and chemical form of the silver halide precipitate as explained, in part, by Corbett (39):

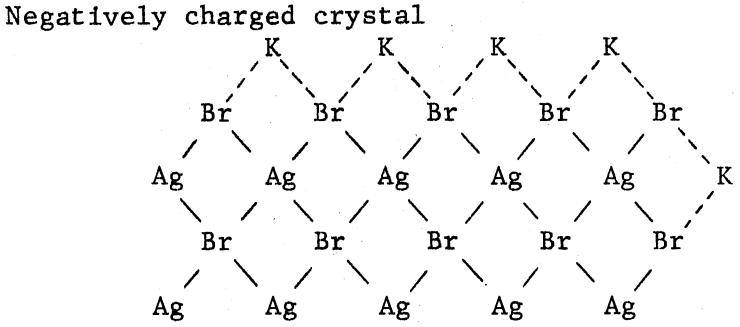
> Silver bromide, on precipitation, possesses a lattice structure. An individual silver ion does not belong to an individual bromine ion but each silver ion is surrounded by six bromine ions and vice versa. The resultant crystal is therefore six faced (a cube); is electrically neutral and has sides which are formed of mixed silver ions and bromine ions. If the crystal is formed from a reaction which has an excess of potassium bromide, the excess Br^- ions in the solution are attracted to the crystal as if they were normal Br^- ions. They are in intimate contact with the surface of the crystal and are thus held strongly in position. As there are no spare Ag^+ ions to confer electrical neutrality upon the resultant crystal, potassium ions, K^+ are attracted to the crystal. The attraction is only weak, because the shape of the K^+ ion does not suit the structure of the silver bromide crystal and the ions are thus free to move away and be replaced by others (p. 64).

But the shape of the silver halide crystals in a photographic emulsion are not simple cubes. Sheppard's microscopic observation showed the crystals to have an octahedral surface in which all of one kind of ion are on the surface. That is to say, the outer surface of the crystal is composed of all Ag^+ or all Br^- ions. The shape of these crystals

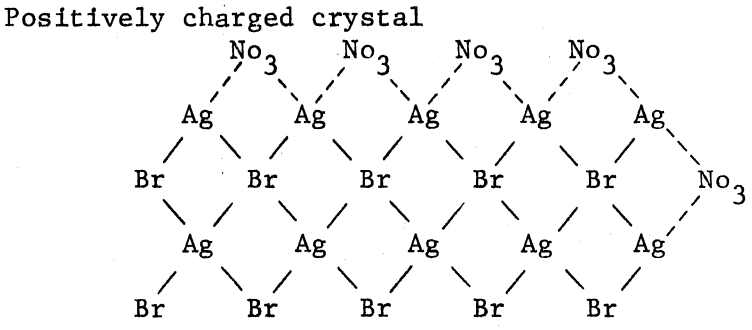
can be explained by observing the cleavage plane in the crystal lattice. It can be seen that two types of crystals are possible:



When a silver bromide crystal is formed, in an excess of alkali halide, it is negatively charged because of its absorbed bromine ion:



On the other hand, if there is an excess of silver nitrate, the reverse change occurs. This is caused by the adsorbed silver ion:



The negatively charged silver bromide crystal is the only one used in photographic emulsions because a positively charged ion is immediately

reduced by developing solutions, whether it is exposed to light or not.

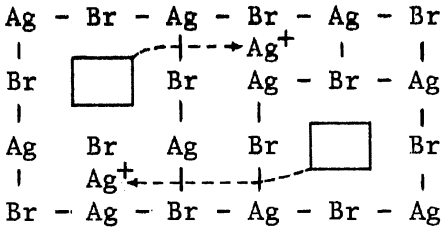
There are then two important crystal characteristics that result from a negative charge. First, the individual crystals of silver halide, prepared with the same kind of excess (alkali halide), possess an electrical charge of the same type and repel all similar crystals. Secondly, the negative charge also repels negatively charged developer ions.

When held in suspension by the gelatin emulsion, the silver bromide crystal is tightly surrounded by the gelatin material and is attached to the grain at various points by the active groups of the gelatin. This attachment produces an inactivation of the grain surface, holding it neutral. The gelatin coating restrains flocculation but does not prevent the groups of the silver bromide grains when a solvent for the silver halide is present. Ammonia or an excess of soluble halide permits the grains to grow despite the presence of the gelatin.

The gelatin appears to contain small quantities of a sulphur compound, allyl isothiocyanate. In the presence of silver halide grains, a complex compound is formed with the crystal and, when the overall solution is alkaline, silver sulphide is formed and is adsorbed to the crystal surface. The points on the crystal where the silver sulphide are formed are referred to as sensitivity centers and correspond to what Sheppard referred to as "specks."

There may also be defects in the silver halide crystal itself. It has been shown experimentally that a perfect crystal of silver halide does not exhibit photosensitivity. Occasionally, a silver ion gets out of place in the lattice work of the crystal and moves into an interstitial position. This phenomenon is known as the Frenkel Defect.

The Frenkel Defect



These defect ions are able to move about the crystal and account for its very small electrical conductivity in the dark.

When light strikes the silver halide crystal, a large increase in the conductivity occurs and the energy in the light is sufficient to liberate electrons from the bromine ions in the crystal. These electrons are able to move freely through the crystal and are therefore available for conduction, while the bromine ions revert to bromine. The energy in the light has been sufficient to create a hole-electron pair in the crystal, as it is found that the bromine atom which is formed, can wander through the silver halide crystal in exactly the same way as can a hole through a crystal of germanium.

According to the Gurney-Mott Hypothesis, the formation of the latent image is the result of the production of photo-electrons in the interior of the silver halide crystals dispersed throughout the emulsion. The usual way in which the action continues is for the bromine atom to diffuse through the crystal to the surface of the grain where it is captured by one of the sensitivity centers or Sheppard's Specks, composed of metallic silver of silver sulphide. This gives the center (speck) a negative charge which attracts one of the silver ions due to the Frenkel defect and the silver ion is converted to metallic silver at the sensitivity center.

While the union of an electron and silver ion at the sensitivity center is the key to the establishment of a latent image, that in itself, does not guarantee its stability.

Upon exposure to light the elements of the crystal will separate as has been previously explained; however, when the light is removed, the silver and bromine will recombine to form silver bromide. The only way the latent image can be preserved is to remove the bromine atom from the chance of recombination.

This, then, is the function of the bromine acceptor in the gelatin. By holding the diffused bromine atom in suspension, the neutralized silver atom remains at the position of the sensitivity center preserving the latent image and awaiting later development.

Two other occurrences are possible. First, the bromine atom is captured by the bromine acceptor as before but the freed electron is directly attached by an interstitial silver ion, creating a secondary internal latent image that is weaker than the surface image. Second, the electron can recombine with the bromine atom. This may occur when the rate of bromine liberation is high and the bromine acceptor outside the crystal is unable to capture the bromine atoms before they are neutralized by the freed electron (39).

There arises, at this point, a difference of opinion with reference to the behavior of the bromine atom at the moment of exposure. Dr. J. W. Mitchell, of Bristol University, postulates that the bromine atoms released during exposure must be trapped in a manner similar to the electrons; however, the more widely accepted theory is that the bromine atoms can move effectively through the crystal by an electronic process in which an electron shifts from a bromine ion to a neighboring atom,

thereby shifting the position of a bromine atom by one lattice position. The bromine atoms can move around as rapidly as the electrons released by the light and are, therefore, of importance in latent image formation (38).

APPENDIX E

CORRESPONDENCE

Oklahoma State University

EDUCATIONAL TELEVISION SERVICES

STILLWATER, OKLAHOMA 74074
COMMUNICATIONS 317
(405) 624-5960

January 19, 1978

Dear Sir:

A study is being conducted by personnel of Educational Television Services at Oklahoma State University into the processing consistency of VNF film stock and your assistance in this effort would be greatly appreciated.

THIS WILL REQUIRE NO ADDITIONAL WORK OR COST ON YOUR PART OR ON THE PART OF YOUR ORGANIZATION.

The purpose of this study is to look at color and density differences among processors of Kodak's video newsfilm stock under normal processing conditions.

The study is being conducted to assess the general processing consistencies among television stations nationwide. In order to show valid comparison of these stations, it is necessary to conduct an identical procedure with a known standard.

Because of the consistency in quality processing demonstrated by professional film laboratories, we are asking you to become a participant in this study. There will be no reference made as to the identity of any television station or film laboratory.

IN RETURN FOR YOUR PARTICIPATION, a report containing a synopsis of the findings and your comparative position in the overall sample, will be forwarded to you upon request. We feel the knowledge gained from this study will provide you and the industry with an insight into the varied degrees of success experienced in the processing of this popular high speed color film.

For additional information about the study, please refer to the enclosed form.

Thank you for your attention.

Sincerely yours,

Dick Coup
Producer/Director

Oklahoma State University

EDUCATIONAL TELEVISION SERVICES

STILLWATER, OKLAHOMA 74074
COMMUNICATIONS 317
(405) 624-5960

January 23, 1978

Dear Mr.

In your capacity as News Director of Station , your assistance in a study, which we feel would be of mutual benefit, would be greatly appreciated. This study is being conducted by personnel of Educational Television Services at Oklahoma State University into the processing consistency of VNF film.

THIS WILL REQUIRE NO ADDITIONAL WORK OR COST ON YOUR PART OR ON THE PART OF YOUR STATION.

The purpose of this study is to look at color and density differences among processors of Kodak's video news film stock under normal processing conditions. This is NOT a process check for any manufacturing company, nor is it an intelligence gathering study to benefit any other film processor. It is an unbiased effort to assess general processing consistencies among television stations nationwide and will be conducted without reference to station identity.

IN RETURN FOR YOUR PARTICIPATION, a report containing a synopsis of the findings and your comparative position in the overall sample, will be forwarded to you, upon request.

We feel the knowledge gained from this study will provide you and the industry with an insight into the varied degrees of success with high speed color film for television purposes.

For additional information about the study, please refer to the enclosed form. Thank you for your attention.

Sincerely yours,

Dick Coup
Producer/Director

I. SAMPLING PROCESS:

Because of the variable nature of film processing, this study will be conducted under carefully controlled experimental conditions and every effort will be made to ensure unbiased handling and subsequent evaluation.

1. All participants will be asked to process three separate control strips (VNF) at intervals of three to four weeks. The processing of these strips should take place right along with the regular work and no special consideration should be given.

2. Samples will be mailed to the participants FIRST CLASS to minimize the time between packaging and processing in order to reduce the chance of contamination due to excess handling. Shipping containers and postage will be supplied by the experimentor.

3. Each control strip shipment will include a short list of instructions for processor handling.

II. DATA INFORMATION:

While this study is not intended to determine causes for processing variation, a close look at conditions under which processing takes place may reveal trends which might encourage further study. Because of this potential, you, as a participant, are being asked to supply information on the following items; however, THE INFORMATION CONTAINED IN THESE ITEMS WILL, IN NO WAY, AFFECT THE MAIN OBJECTIVES OF THE STUDY AND YOUR PARTICIPATION DOES NOT OBLIGATE YOU IN ANY WAY TO COMPLETE THIS FORM.

Please check or fill in the appropriate answers below:

1. Brand of film processor: _____
(Manufacturer)

2. Brand of chemicals preferred: ☐ Kodak ☐ Hunt

3. Number of days per week that film processor is in operation:
☐ 1 - 3 ☐ 4 - 5 ☐ 6 - 7

4. Average number of hours per day that film processor is in operation:
☐ 1 - 3 ☐ 3½ - 6 ☐ 6½ - 9 ☐ more than 9

5. Estimated daily average footage processed:
☐ Under 500 ☐ 500 - 1000 ☐ 1000 - 2000 ☐ more than 2000

6. Film other than VNF processed in this machine:
☐ None ☐ EF ☐ EFB ☐ ECO ☐ MS ☐ Other _____
(Specify)

7. Commercial processing service offered to outside customers:
☐ Yes ☐ No

8. Procedures for quality control:
☐ Visual observation ☐ Control strip (In-house analysis)
☐ Control strip (Outside service analysis)

Should you choose to become a participant, please indicate below along with the name and address of the person who will receive the final results upon completion of the study.

We would like to participate in this study on processing consistency of VNF film stock. Please send our copy of the final results to:

_____

_____

_____

We would prefer not to participate in this study.

REASON: (Optional)_____

_____

Please return this form in the enclosed envelope. If your response is affirmative, you will be contacted as soon as the sample selection has been completed.

Thank you for your attention.

Dick Coup
Principal Experimenter

March 6, 1978

Dear

The selection process for participants in the study on processing consistency has been completed and we are happy to inform you that your organization has been included in the study sample.

The first trial control strip for VNF-1 processing will be arriving within the next week and will be accompanied by concise instructions for handling and processing.

We would like to take this opportunity to thank you for your willingness to participate in this study and we look forward to sharing the findings with you, upon its completion.

Sincerely yours,

Dick Coup

PROCESSING INSTRUCTIONS FOR FIRST TRIAL

This is the first of three VNF-1 control strips to be processed by your system in conjunction with the study design on film processing consistency.

The following is an outline of the contents of this package and instructions for handling:

1. One cover letter/instruction sheet.
   To be used as a guide for the handling, processing and return of experimental materials.

2. One VNF-1 control strip inside light-tight container.
   Please process on Friday, March 17, 1978 at a time of your convenience, following the first processing run of the day. If no film is processed on this date, please process on the last day of the weekly schedule.

3. One SEALED light-tight container.
   PLEASE DO NOT OPEN. Contents include one VNF-1 control strip for MAIL CHECK ONLY. Leave attached to the inside of the mailer.

4. Return postage.

5. Return address label.

After the control strip is processed, please return it to the light-tight container and place the container in the mailer. Use the enclosed postage and address label for return shipment. Seal and send out with the regular business mail at your earliest convenience.

The second trial control strip will be mailed to you in this same coded mailer within three weeks of the first trial completion.

Our thanks again for your participation in this study.

Dick Coup

PROCESSING INSTRUCTIONS
FOR THE SECOND TRIAL

This is the second of three VNF-1 control strips to be processed by your system in conjunction with the study design on film processing consistency.

Please process the enclosed control strip on or as near to MONDAY, MAY 1st as your schedule permits.

After processing, place the control strip back into its sample container and seal inside the enclosed, stamped return mailer.

The third and last of the sample control strips will be mailed to you within three weeks of the second trial completion.

Again, we would like to thank you for your time and effort to make this film processing study possible.

Dick Coup
Principal Experimenter

PROCESSING INSTRUCTIONS FOR THE THIRD TRIAL

This is the third and last of three VNF-1 control strips to be processed by your system in conjunction with the study design on film processing consistency.

These three trials have been widely spaced in order to assure a degree of reliability between the samples. Please process this strip on, or as near to, Wednesday, July 5th, as possible and return it in the sample container by means of the enclosed self-addressed mailer.

Overall data analysis will begin with the return of this sample and results will be mailed to you upon study completion.

Again, we thank you for your time and effort to make this film processing study possible.

Sincerely,

Dick Coup

APPENDIX F

INDIVIDUAL PROCESSOR PERFORMANCE CHARTS

The following are individual performance charts for each of the participants in this study. The data obtained from each of the three trials is included along with a graphic analysis of the Trial-to-Trial performance.

The scale to define the Density Level and deviation from the manufacturer's standard is located vertically in the column at the left of the chart. Also located in this section is the Color Legend, Color Balance Standard parameters for Density Levels 4 and 7, and the Processor Identification Code.

The vertical section at the right of the chart contains the comparative deviation measurements obtained by densitometric analysis from all three trials. Trial designation is located at the top of the chart and Density Levels are positioned from Level 1 at the bottom, to Level 11 at the top. The Colors are arranged vertically to correspond with the Density Levels and are designated as R = Red, G = Green, and B = Blue.

The center column is a graphical plotting of the three trials from left to right, as indicated at the top of the chart. The numbers at the bottom identify the position in which the processor placed as compared to the other processors within the same group. Connecting lines are drawn from the "zero" point of the scale through the three colors by Density and Trial in order to graphically illustrate the direction and consistency of processing performance.

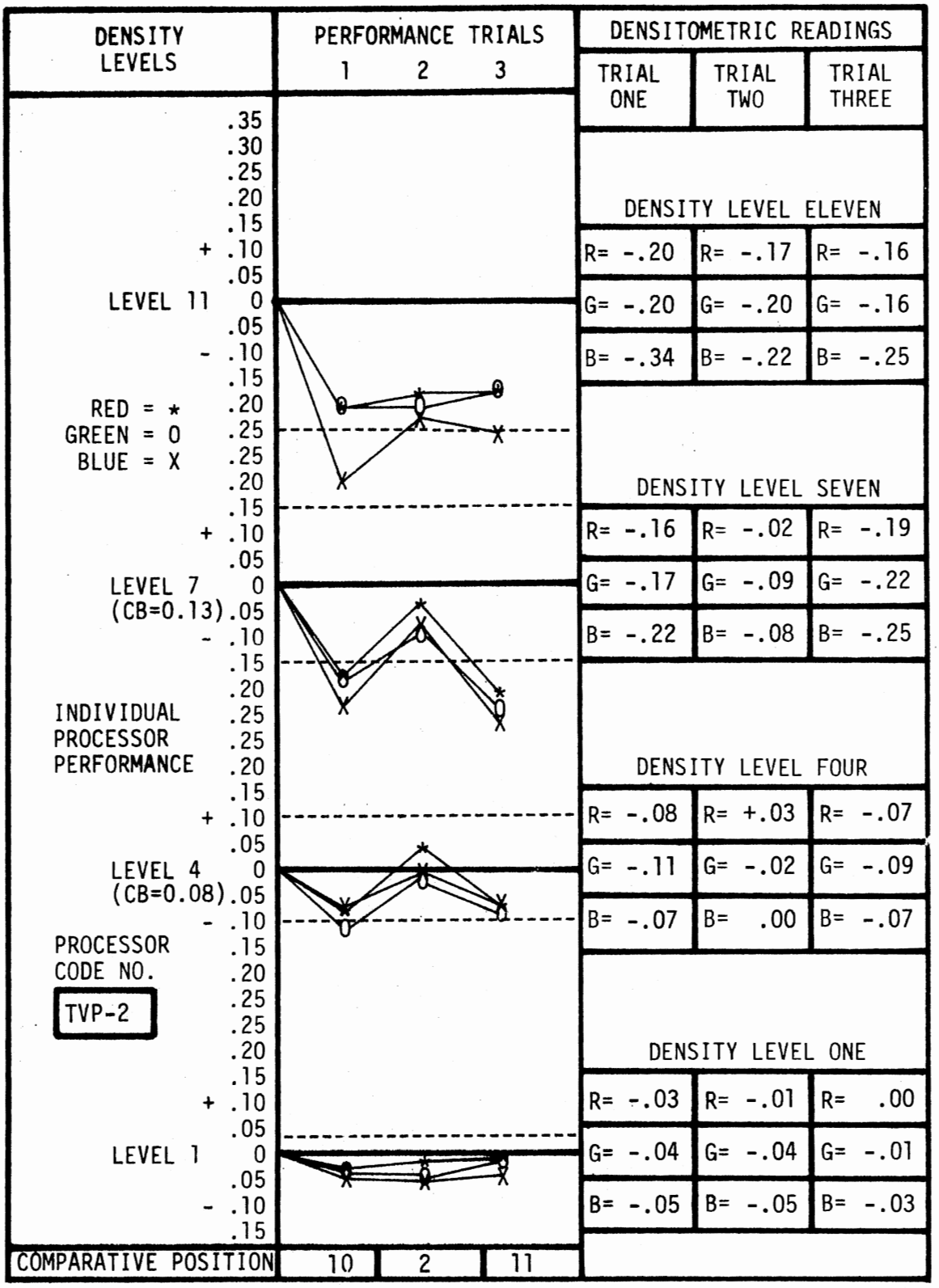


Figure 10. Individual Processor Performance, TVP-2

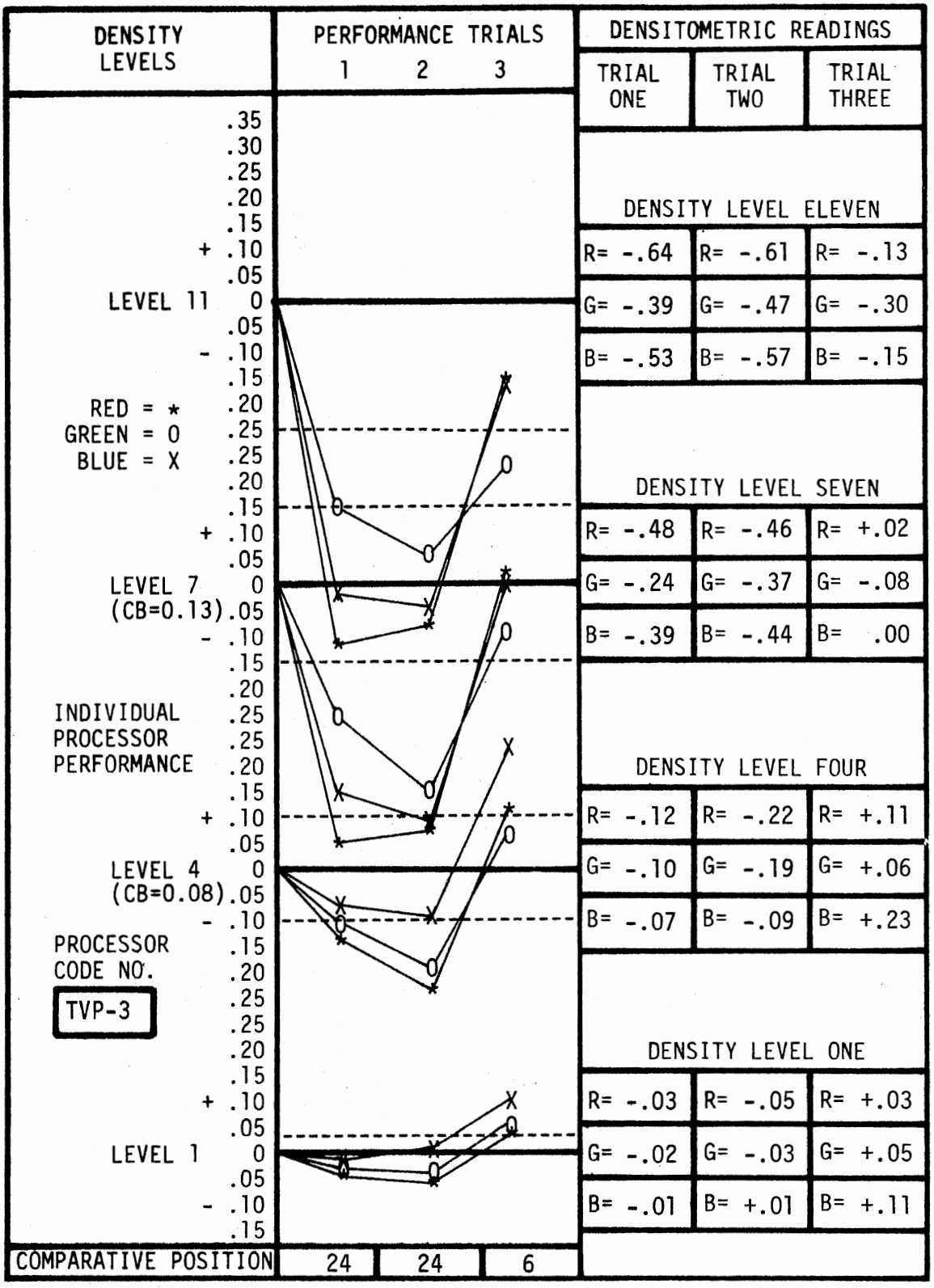


Figure 11. Individual Processor Performance, TVP-3

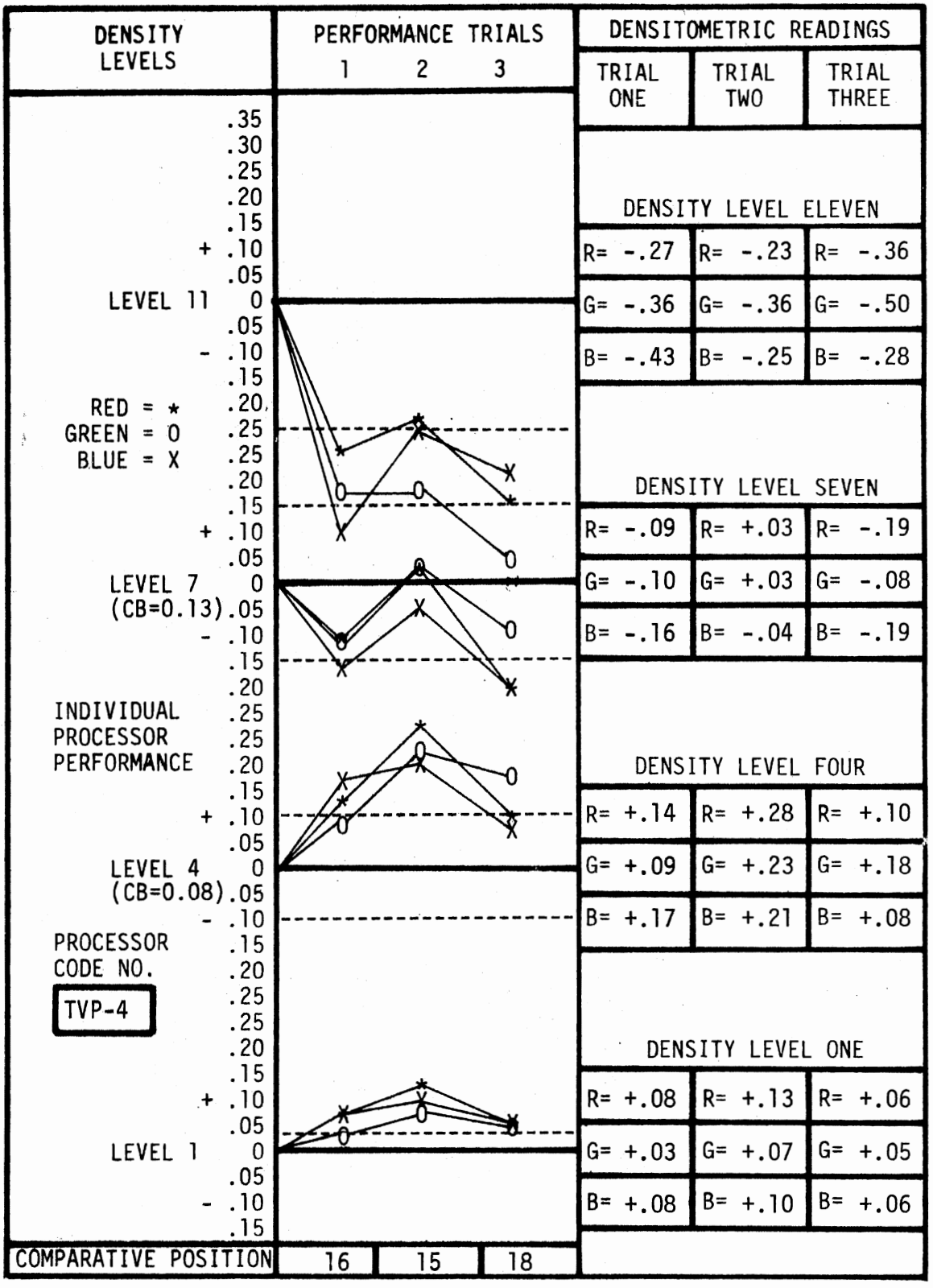


Figure 12. Individual Processor Performance, TVP-4

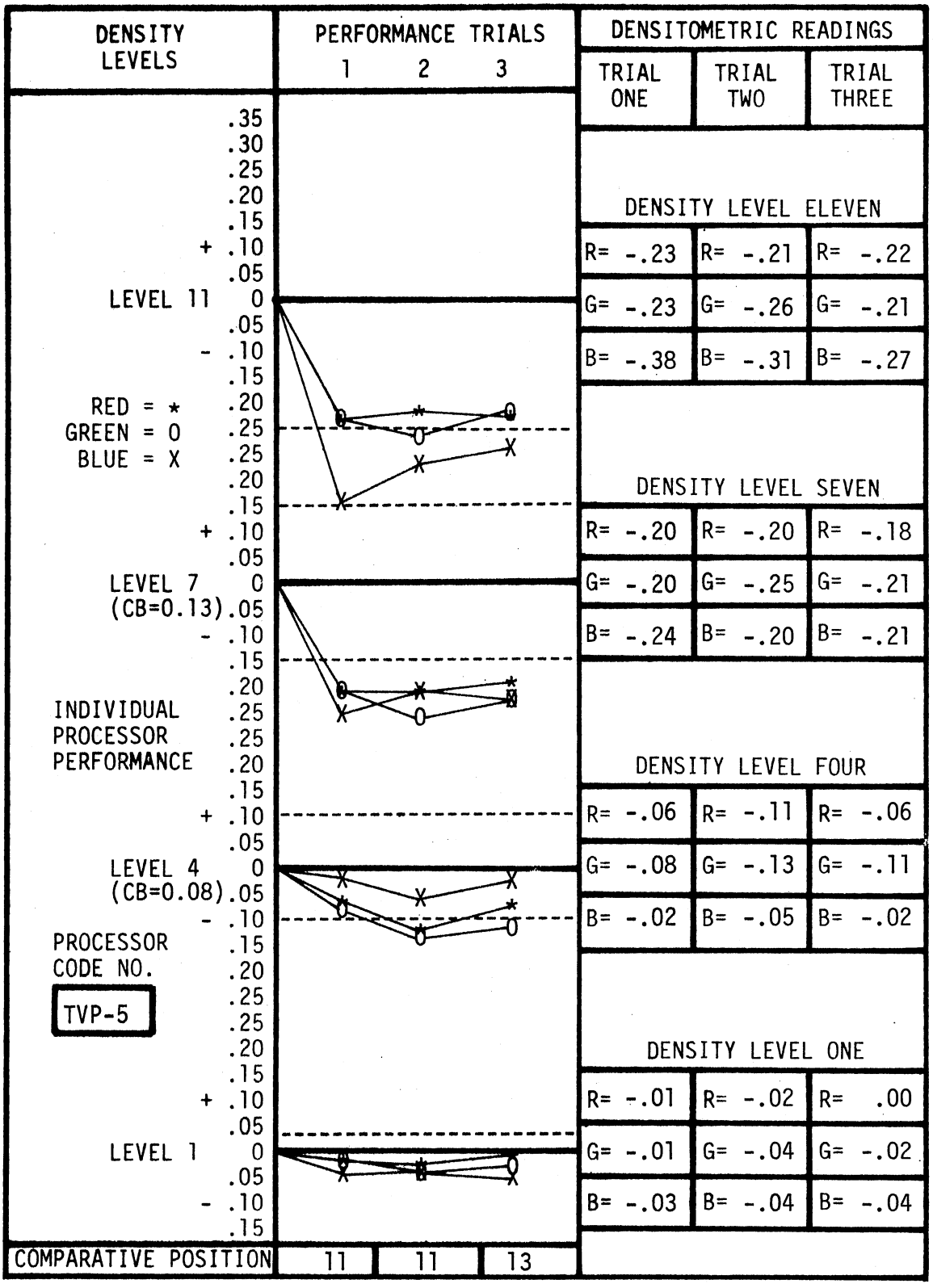


Figure 13. Individual Processor Performance, TVP-5

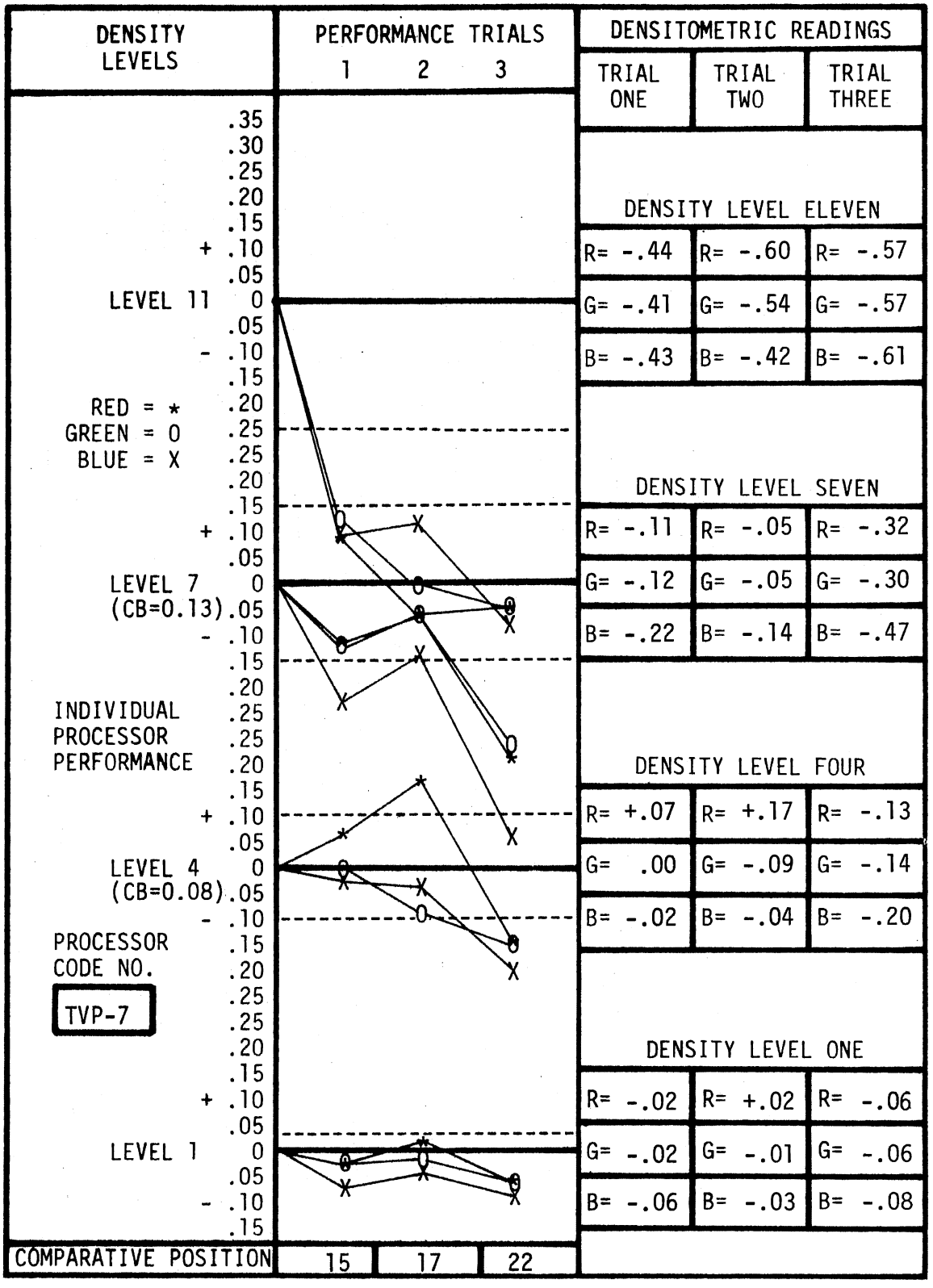


Figure 14. Individual Processor Performance, TVP-7

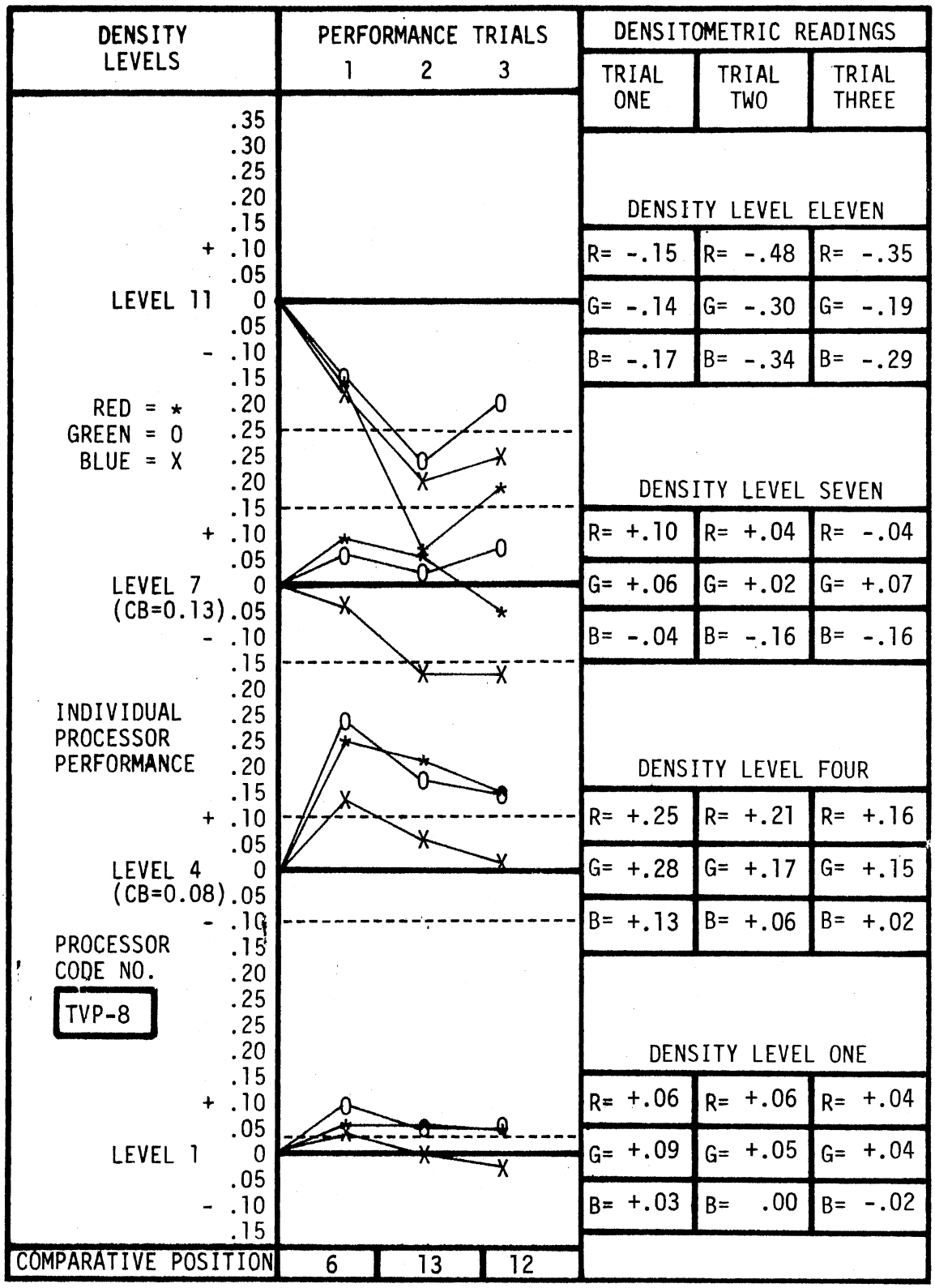


Figure 15. Individual Processor Performance, TVP-8

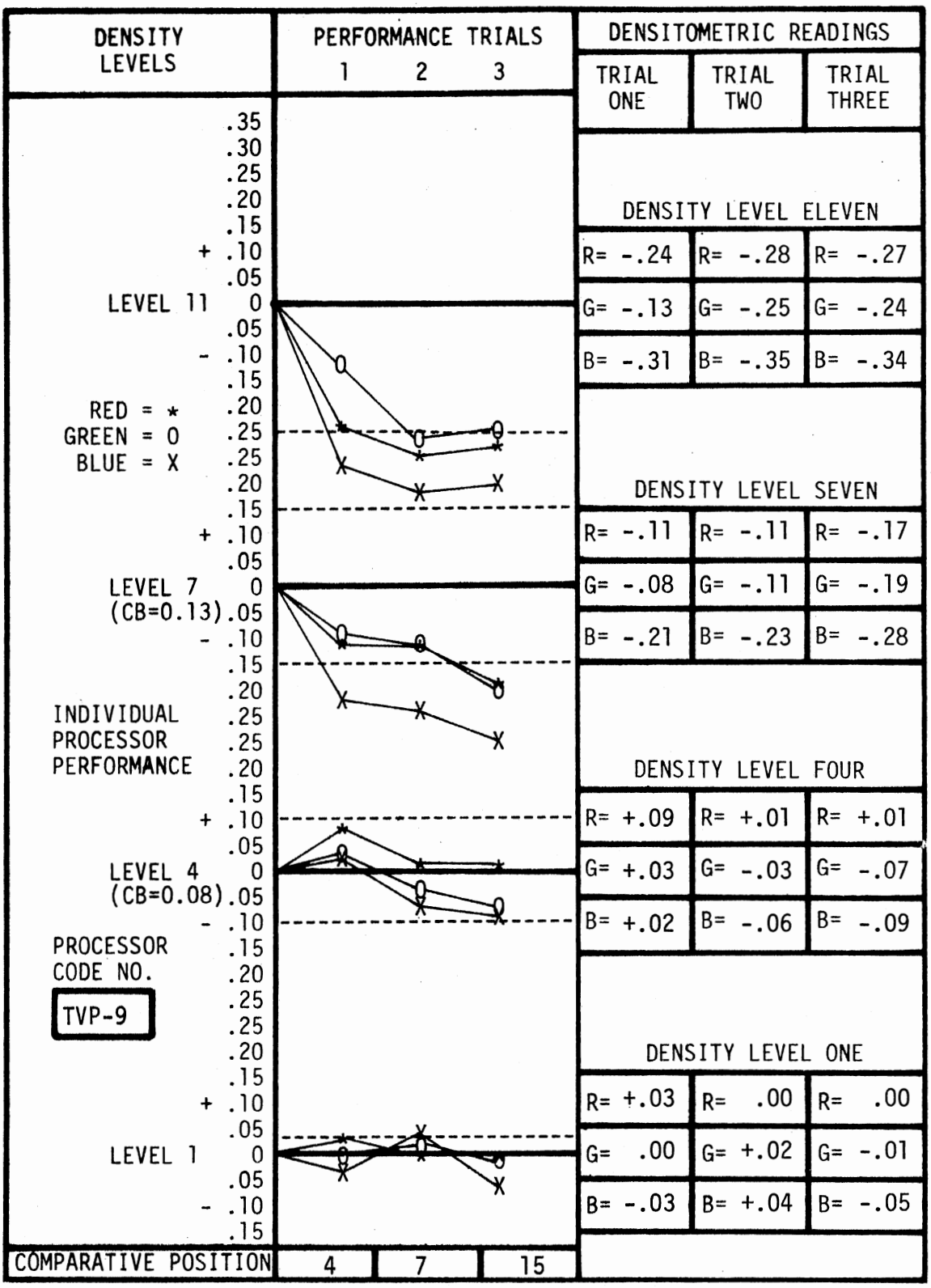


Figure 16. Individual Processor Performance, TVP-9

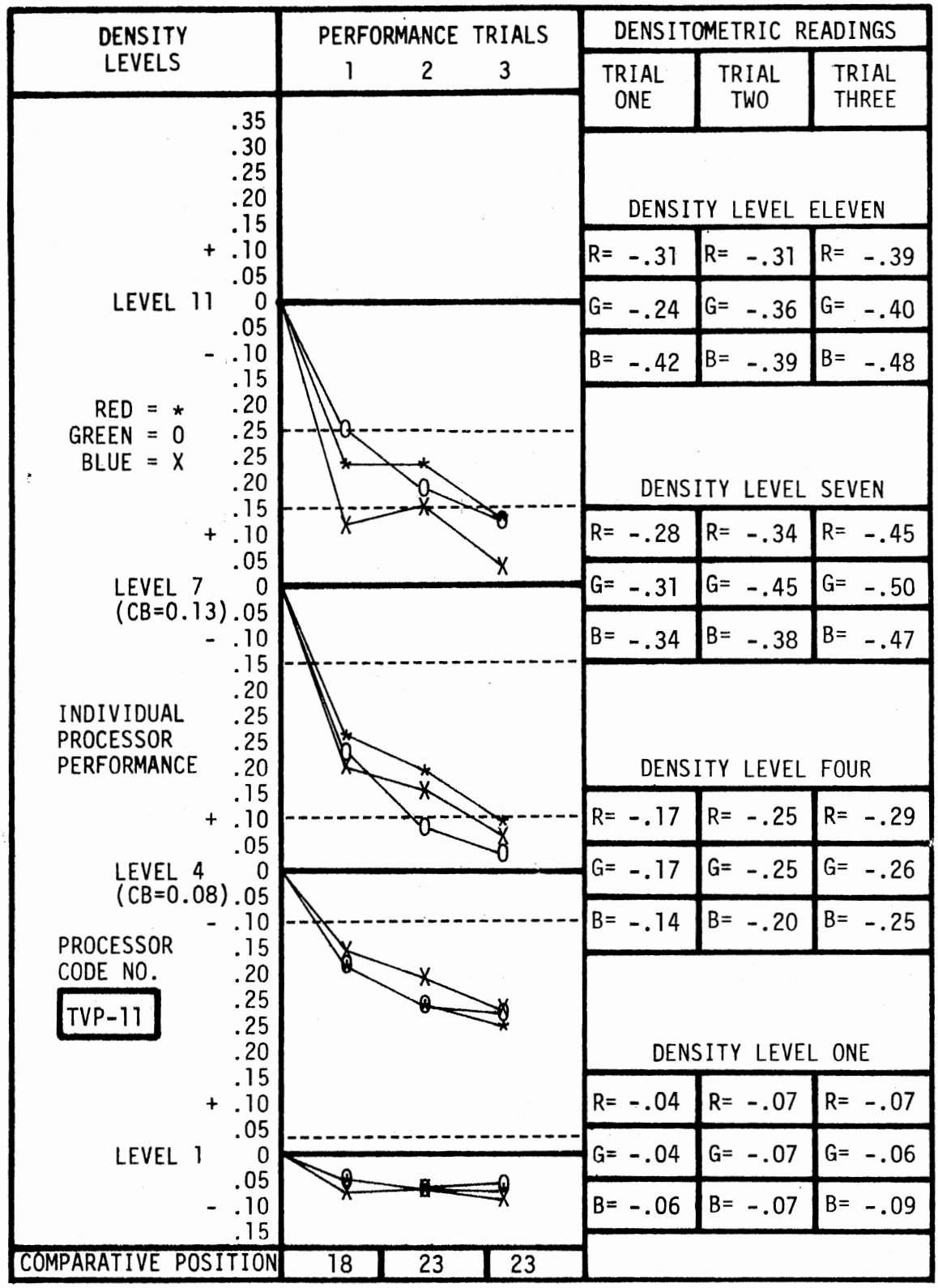


Figure 17. Individual Processor Performance, TVP-11

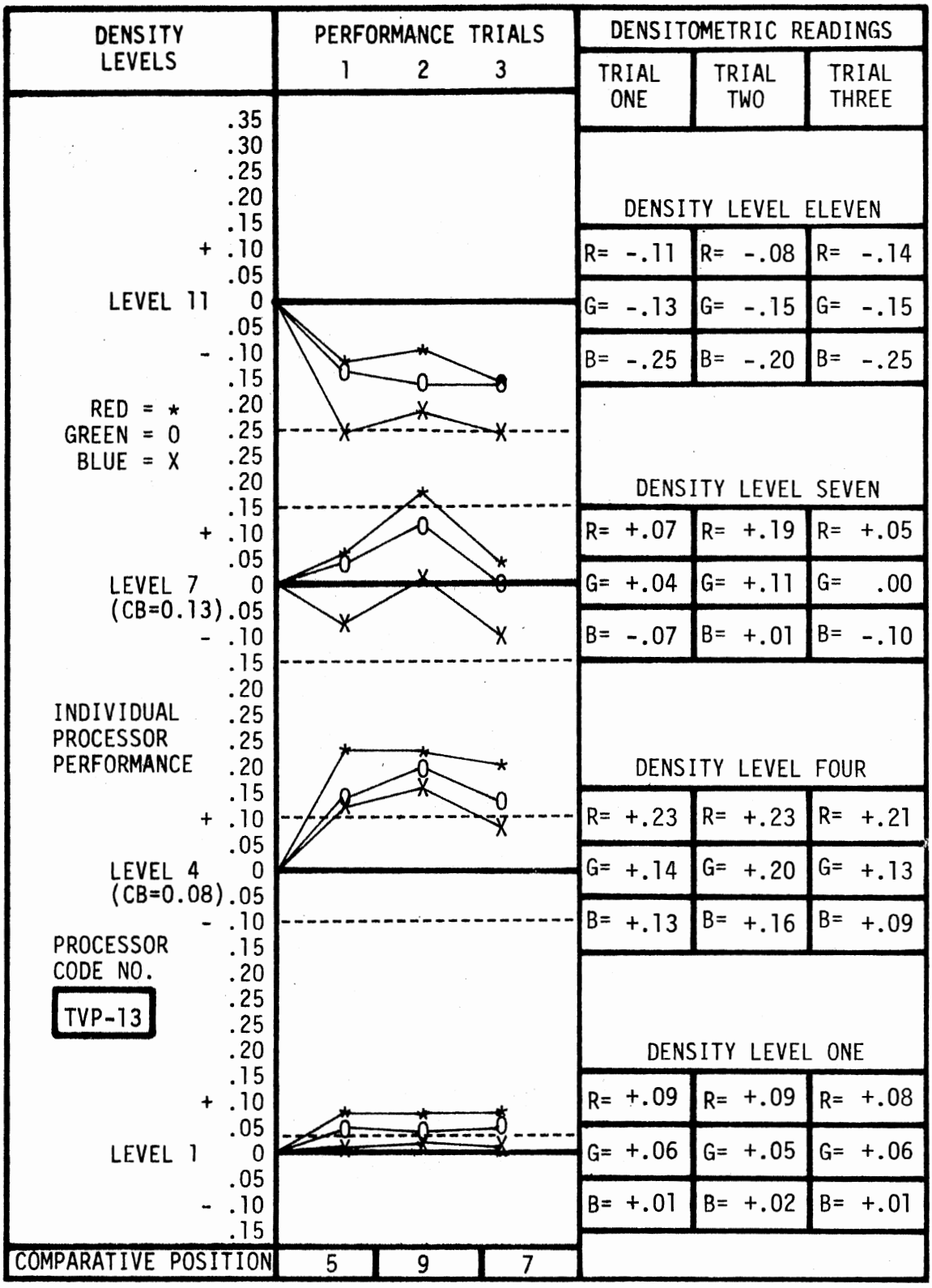


Figure 18. Individual Processor Performance, TVP-13

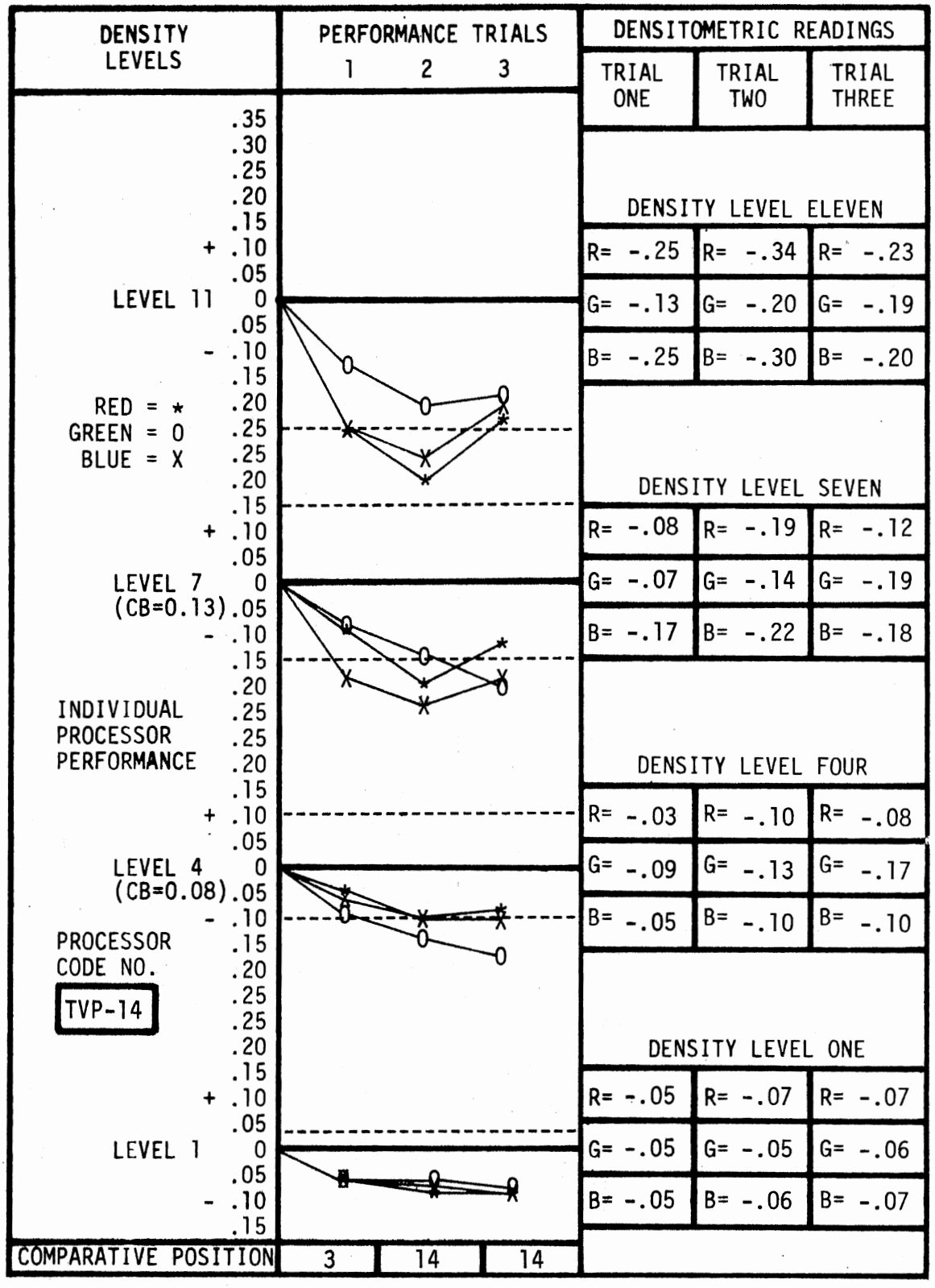


Figure 19. Individual Processor Performance, TVP-14

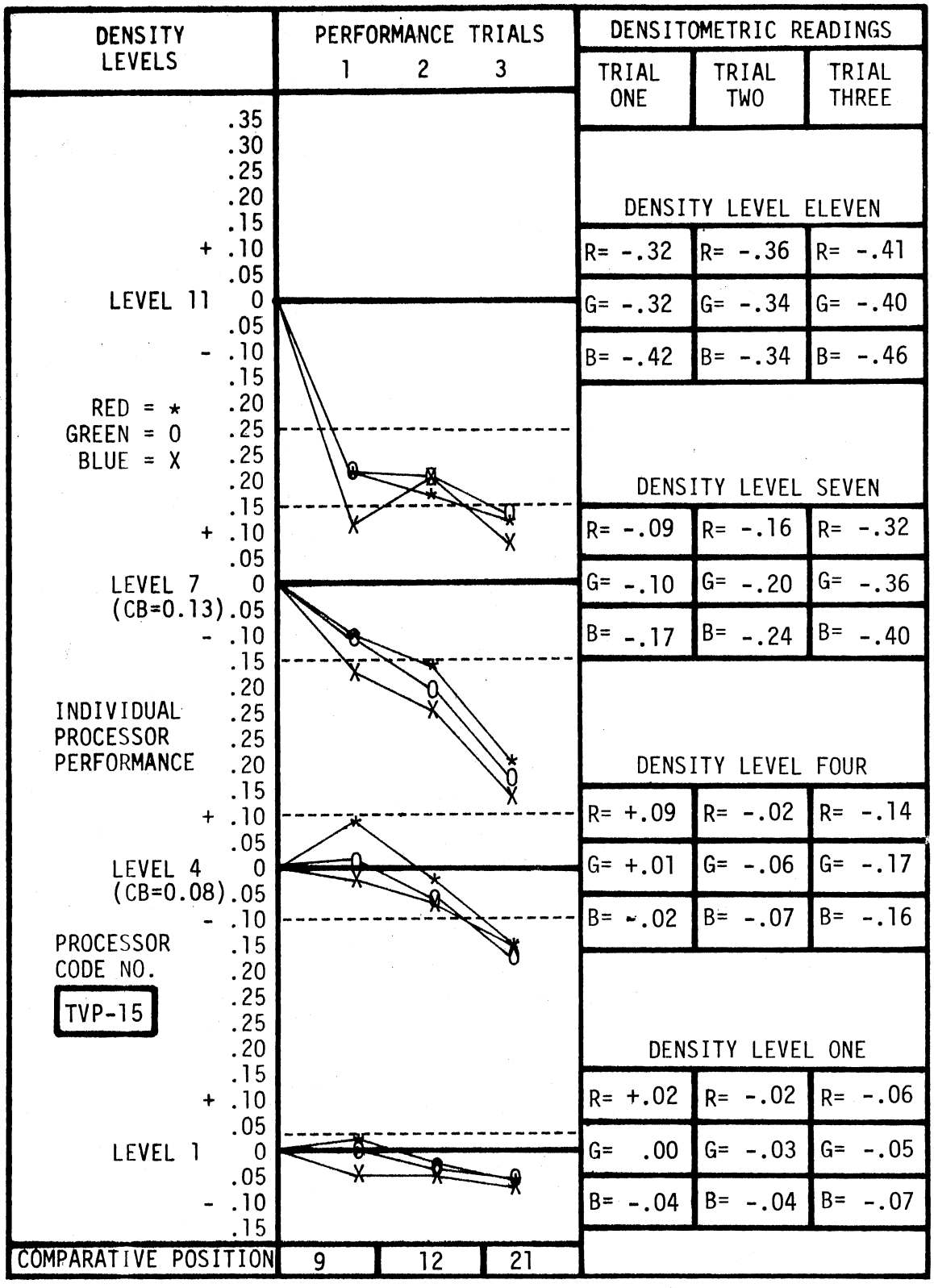


Figure 20. Individual Processor Performance, TVP-15

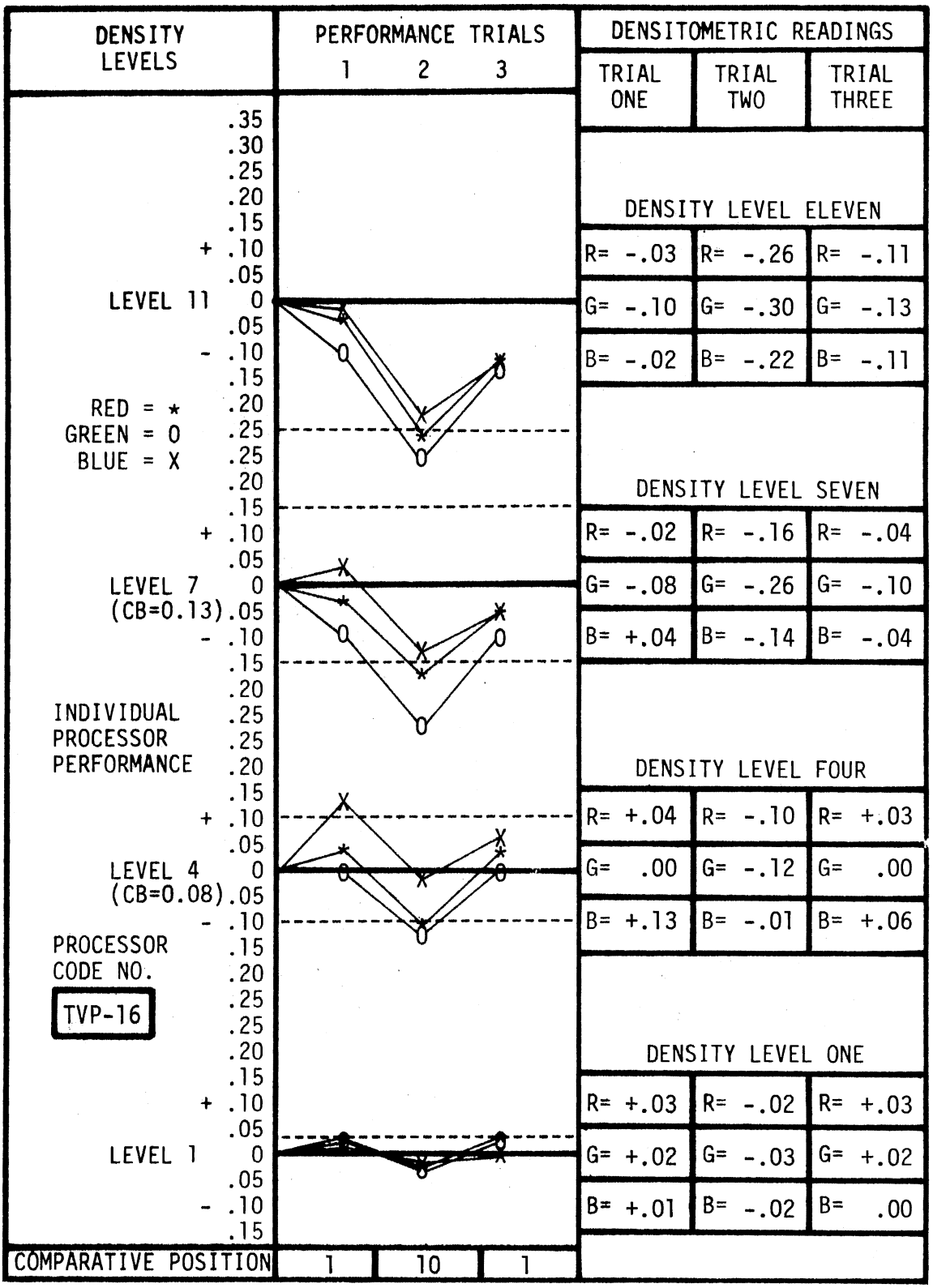


Figure 21. Individual Processor Performance, TVP-16

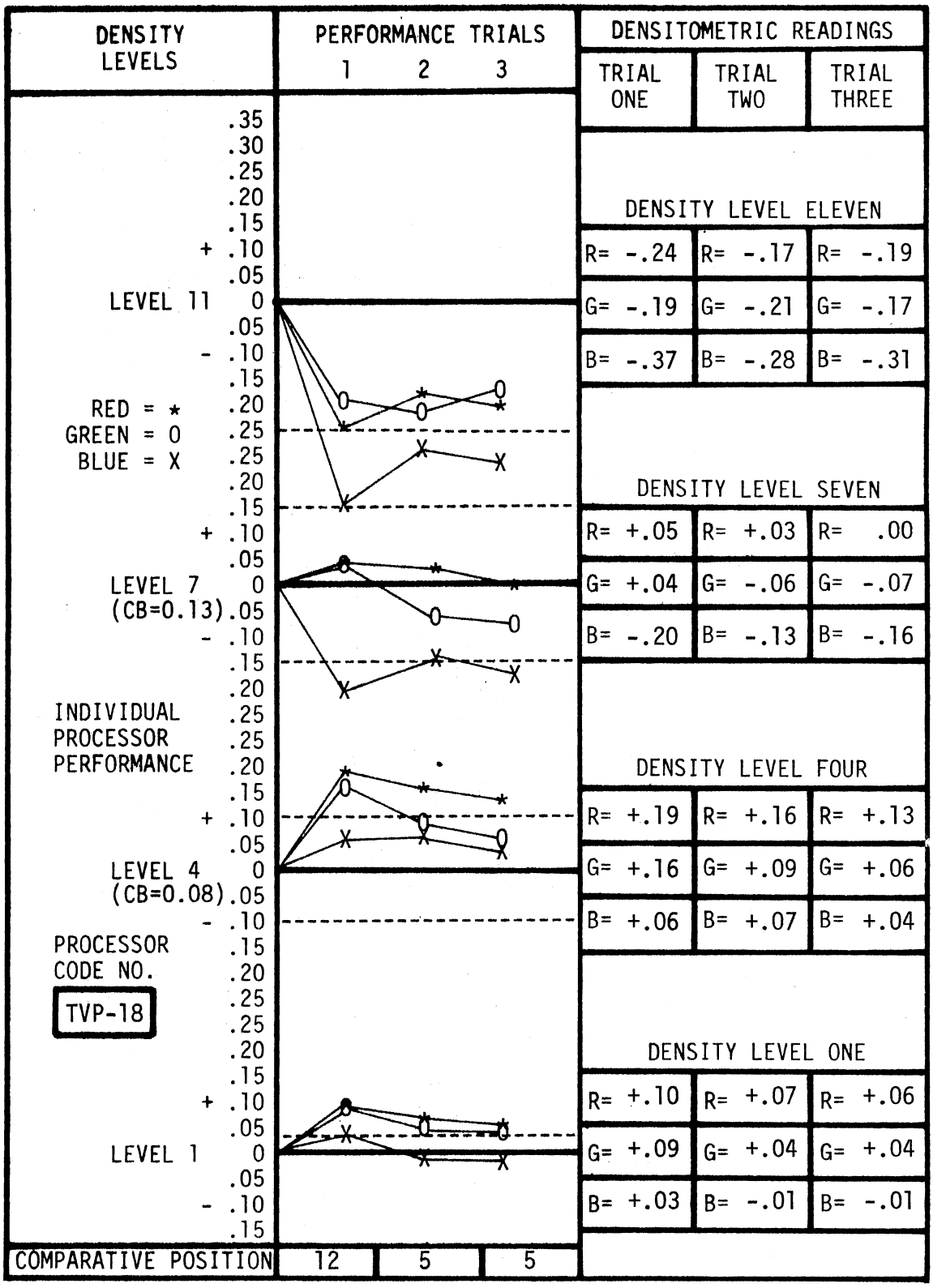


Figure 22. Individual Processor Performance, TVP-18

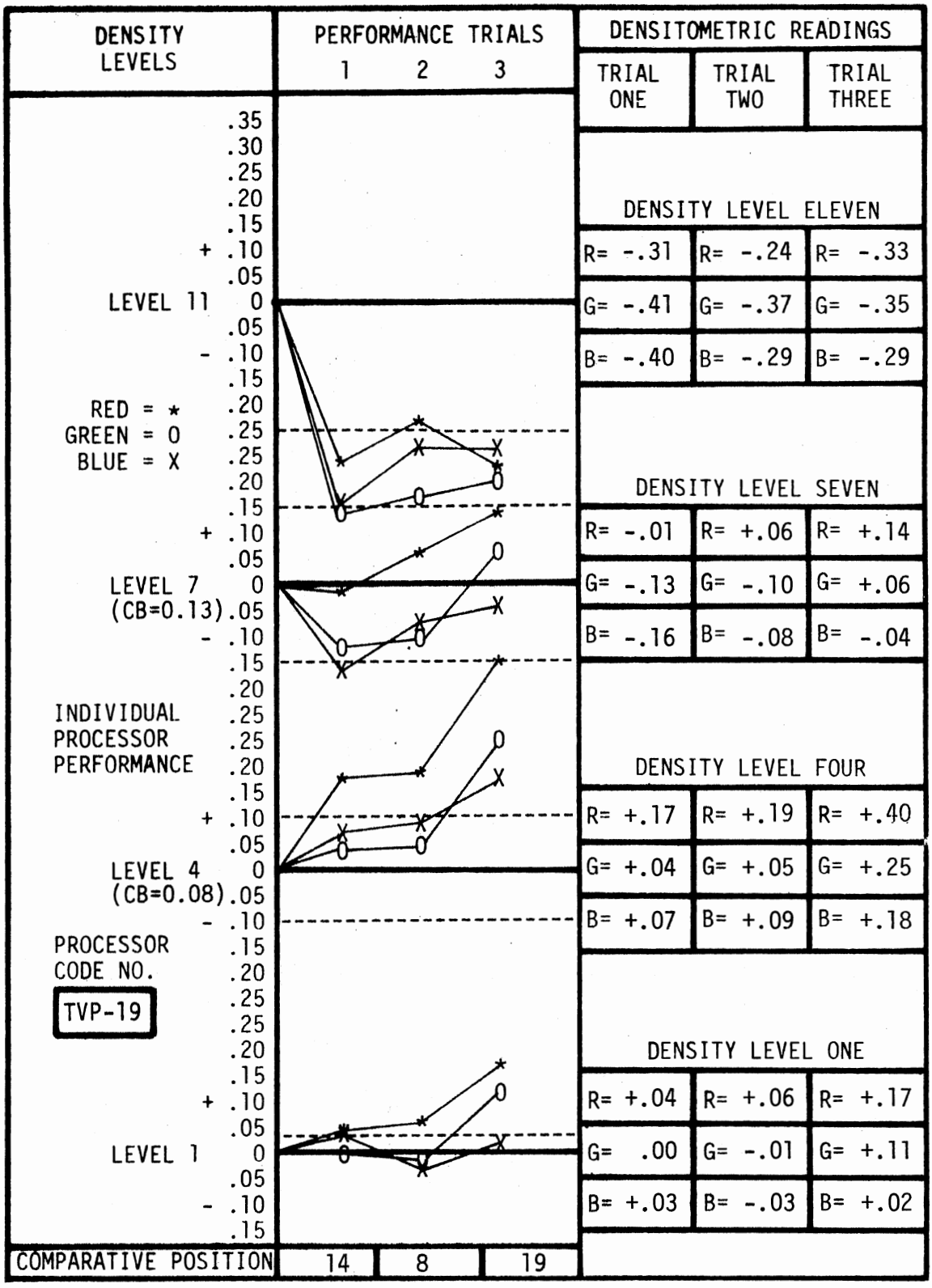


Figure 23. Individual Processor Performance, TVP-19

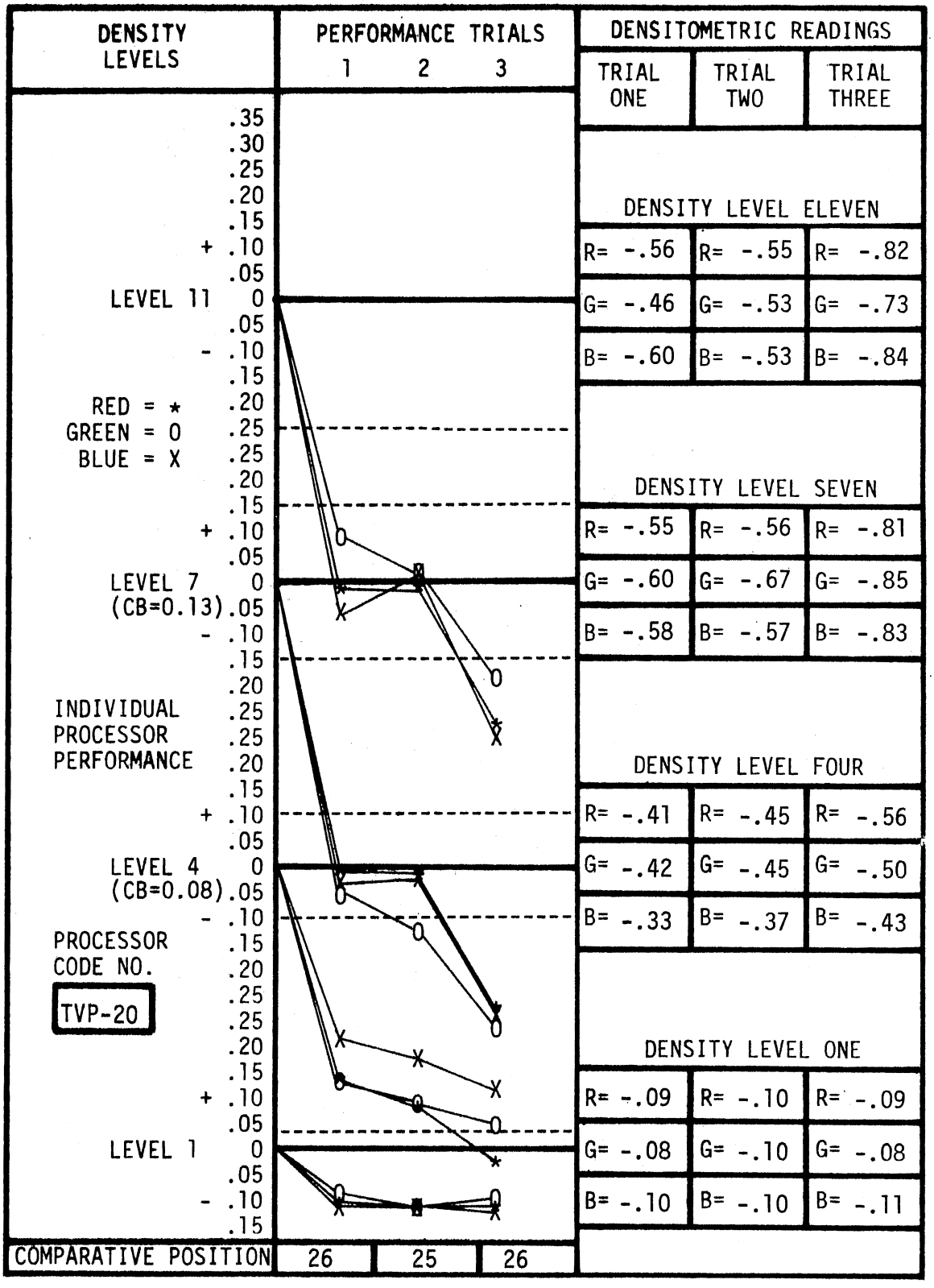


Figure 24. Individual Processor Performance, TVP-20

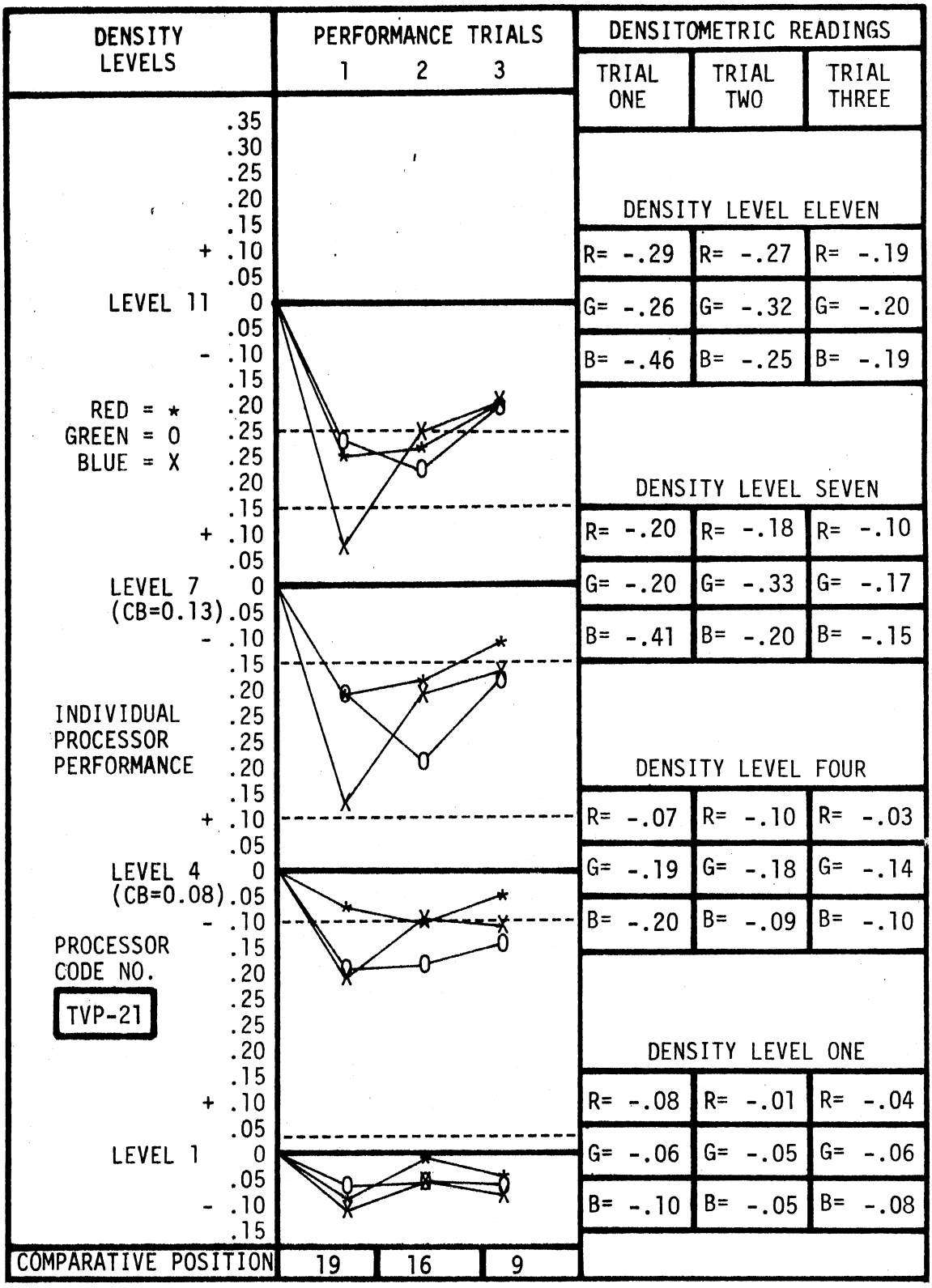


Figure 25. Individual Processor Performance, TVP-21

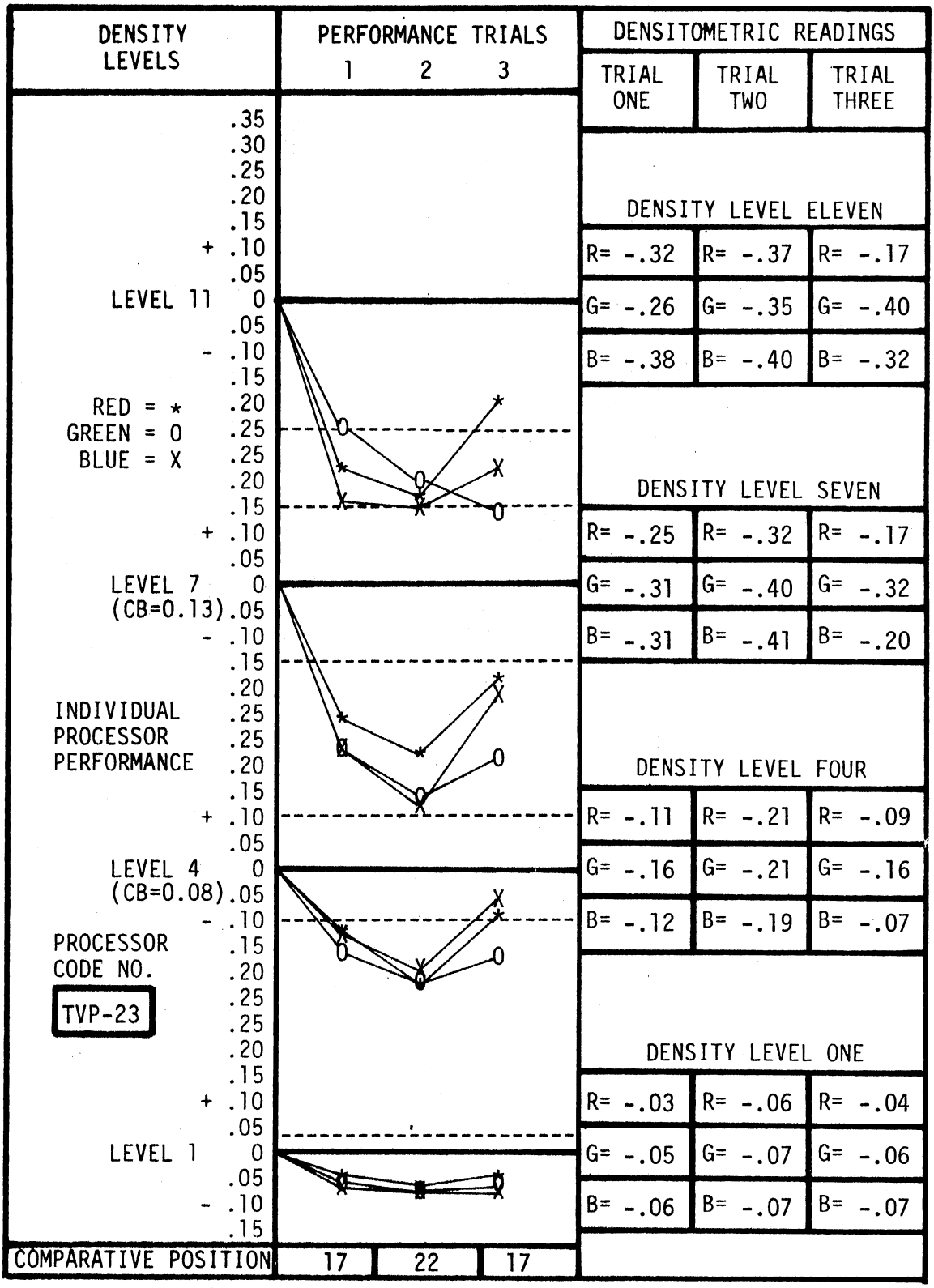


Figure 26. Individual Processor Performance, TVP-23

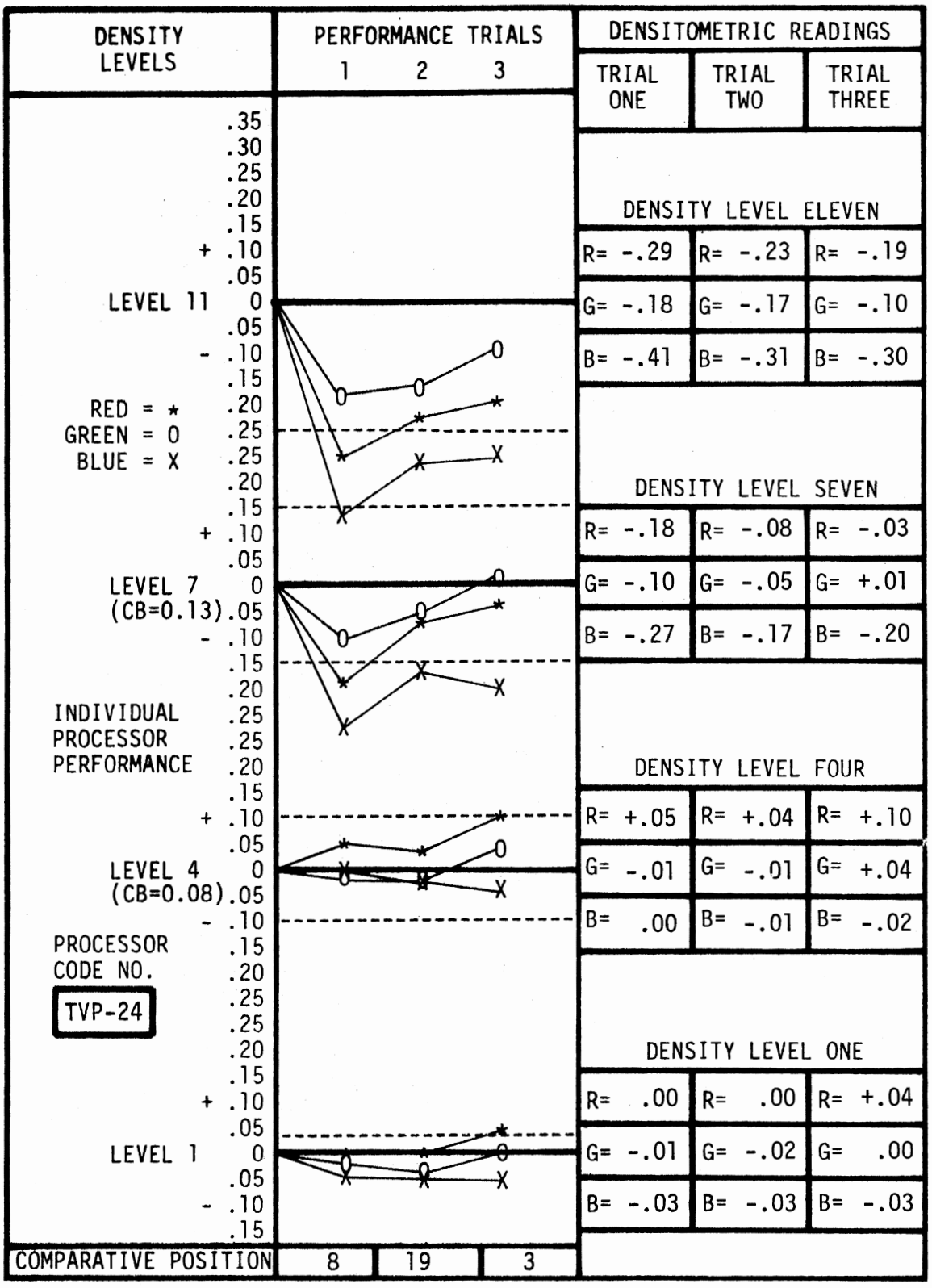


Figure 27. Individual Processor Performance, TVP-24

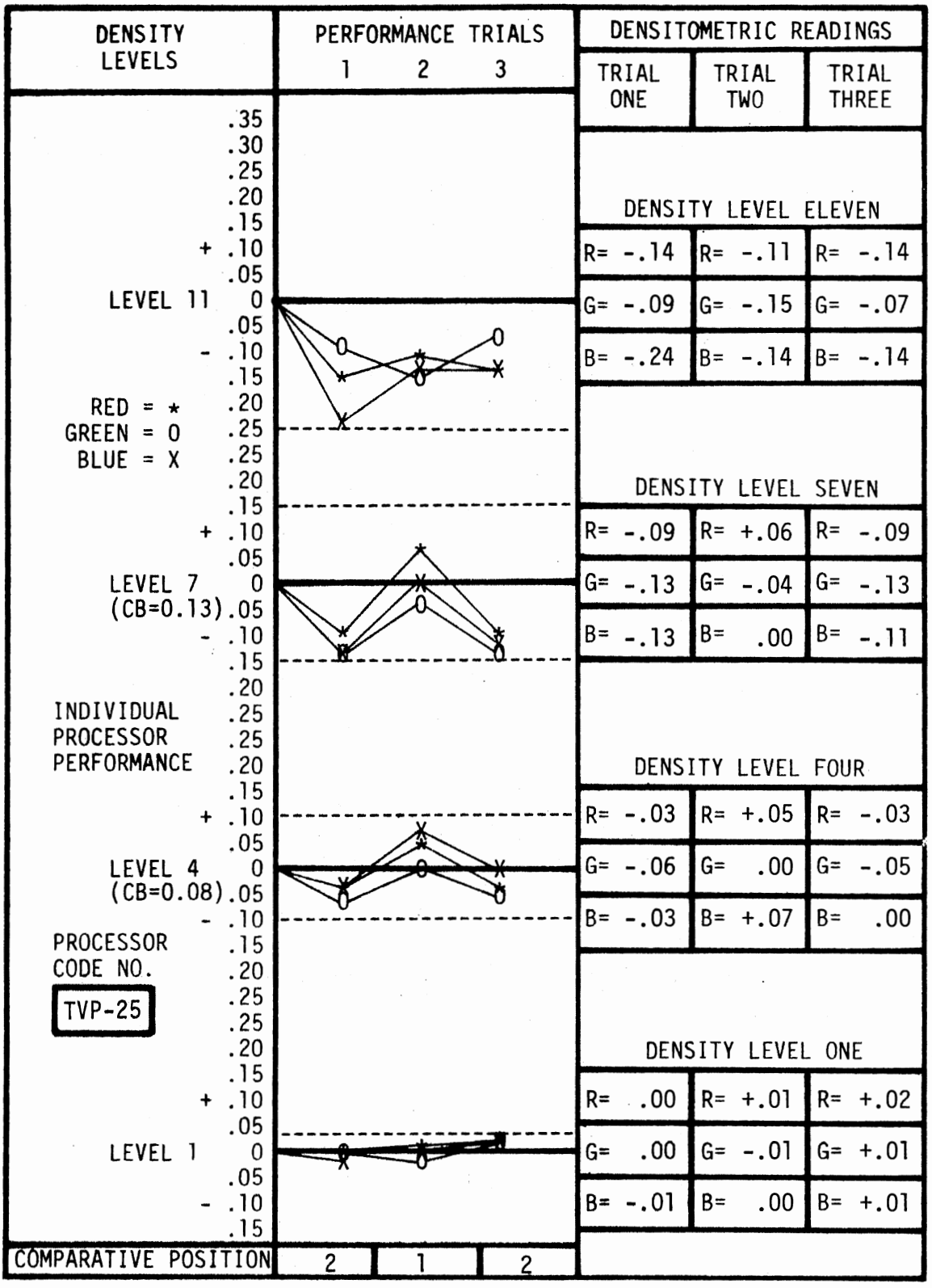


Figure 28. Individual Processor Performance, TVP-25

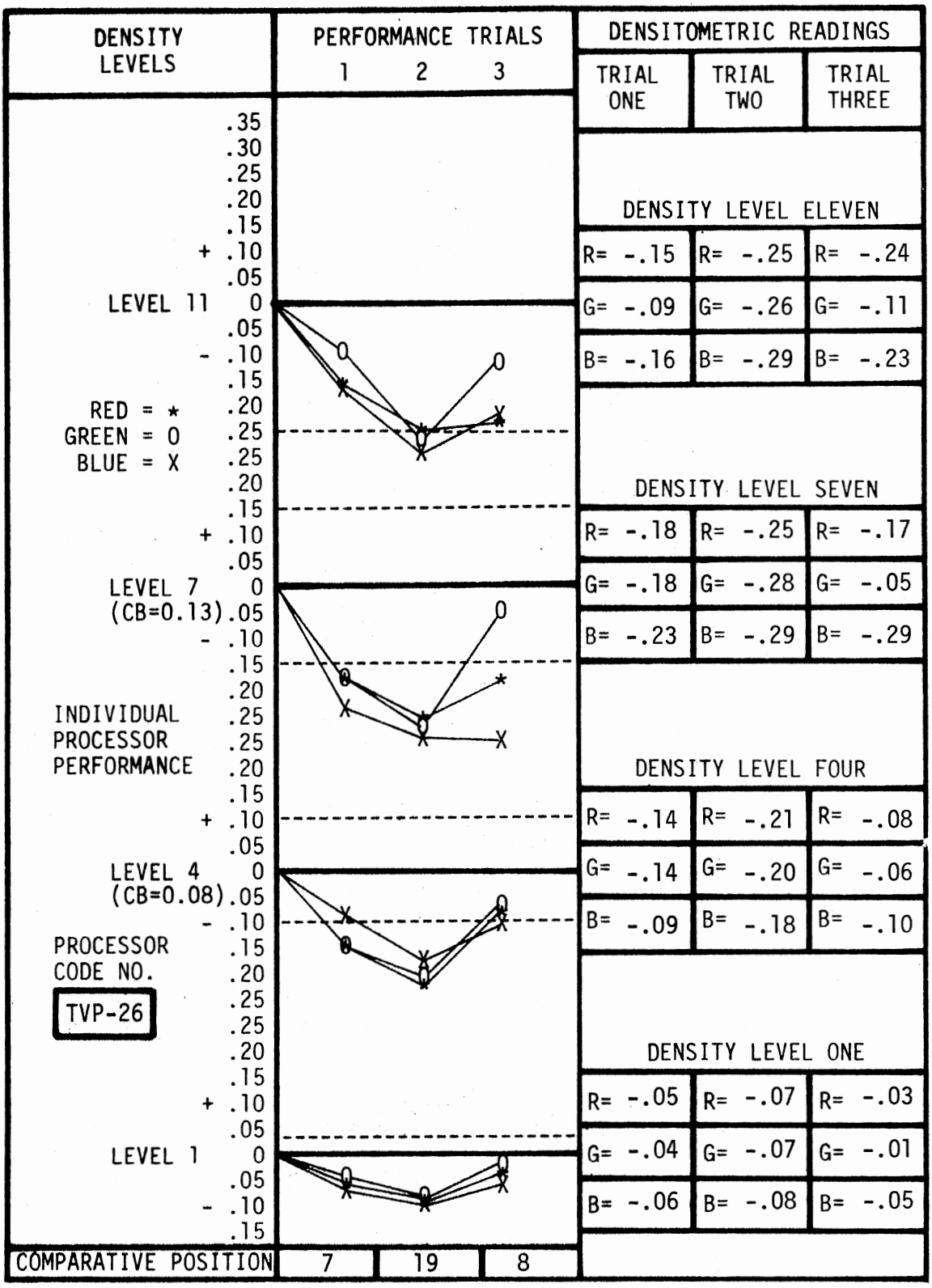


Figure 29. Individual Processor Performance, TVP-26

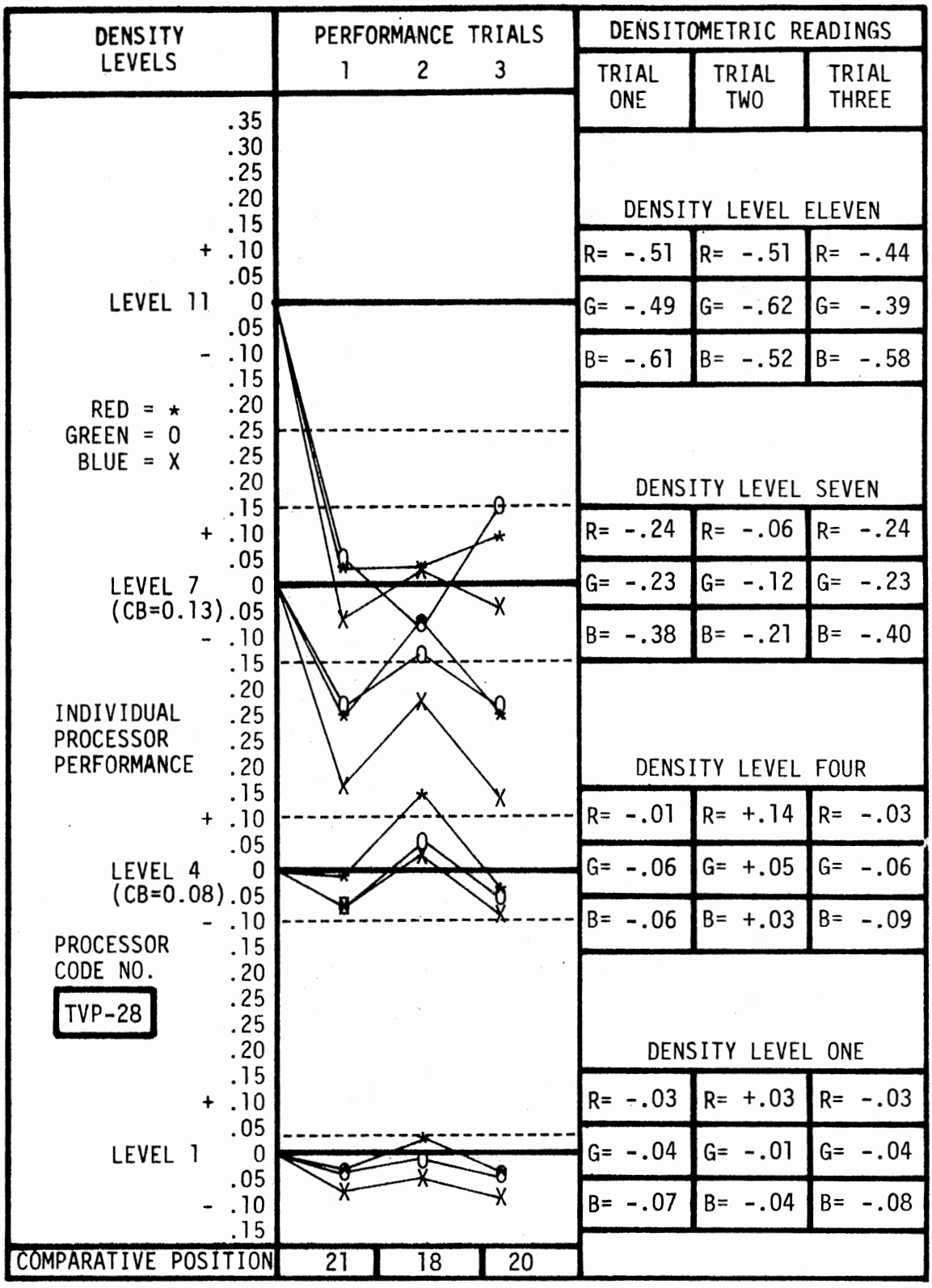


Figure 30. Individual Processor Performance, TVP-28

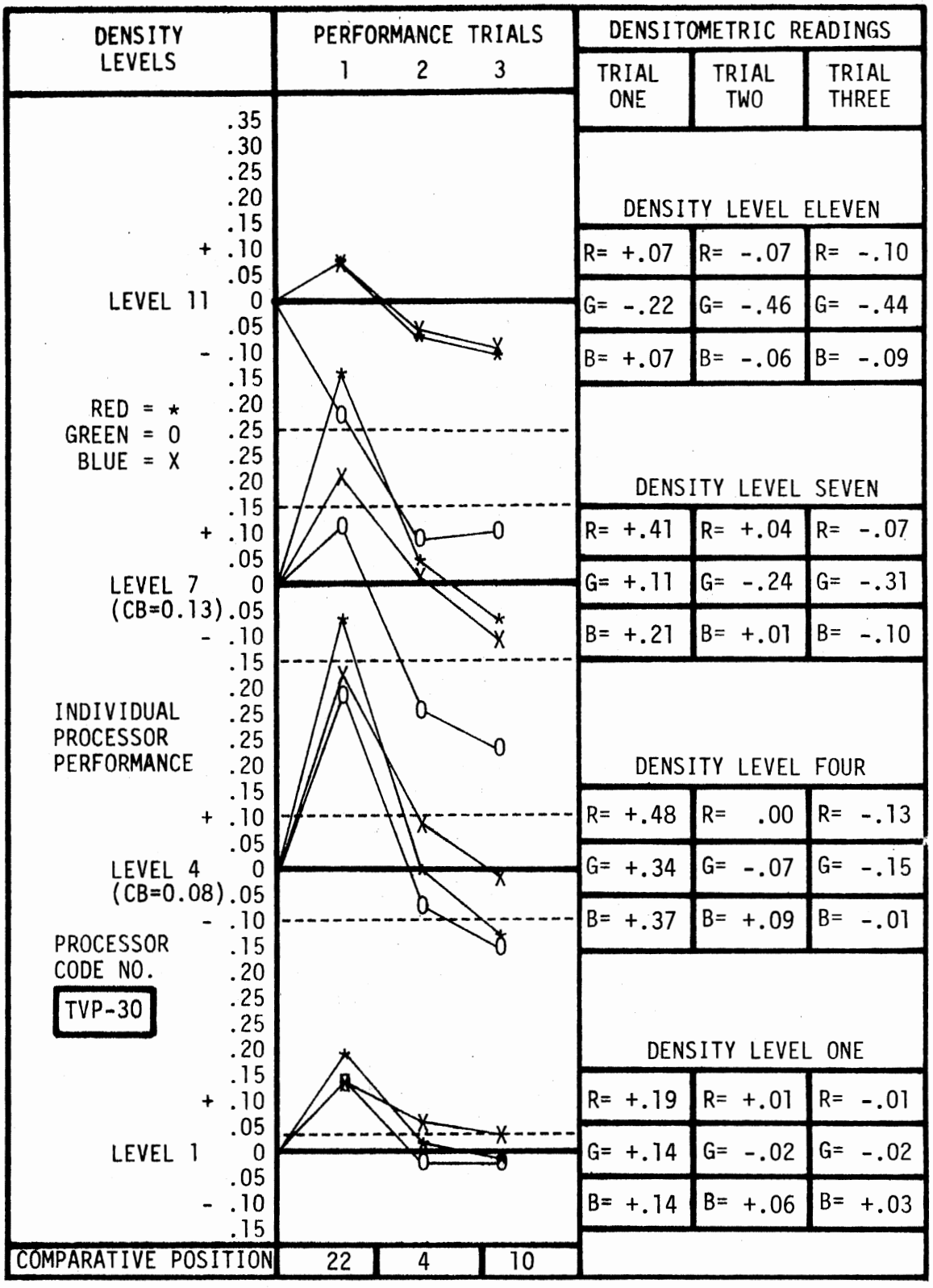


Figure 31. Individual Processor Performance, TVP-30

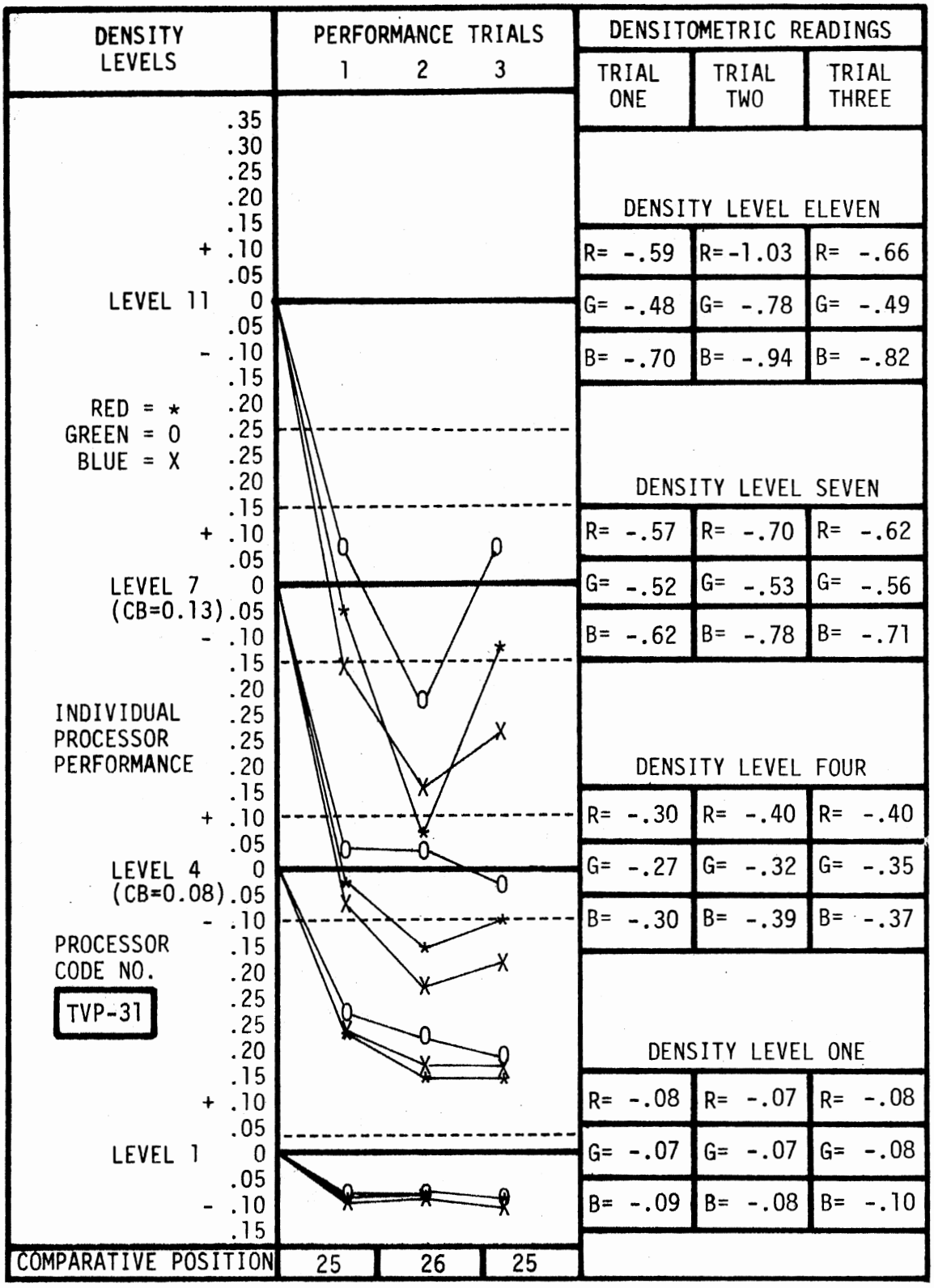


Figure 32. Individual Processor Performance, TVP-31

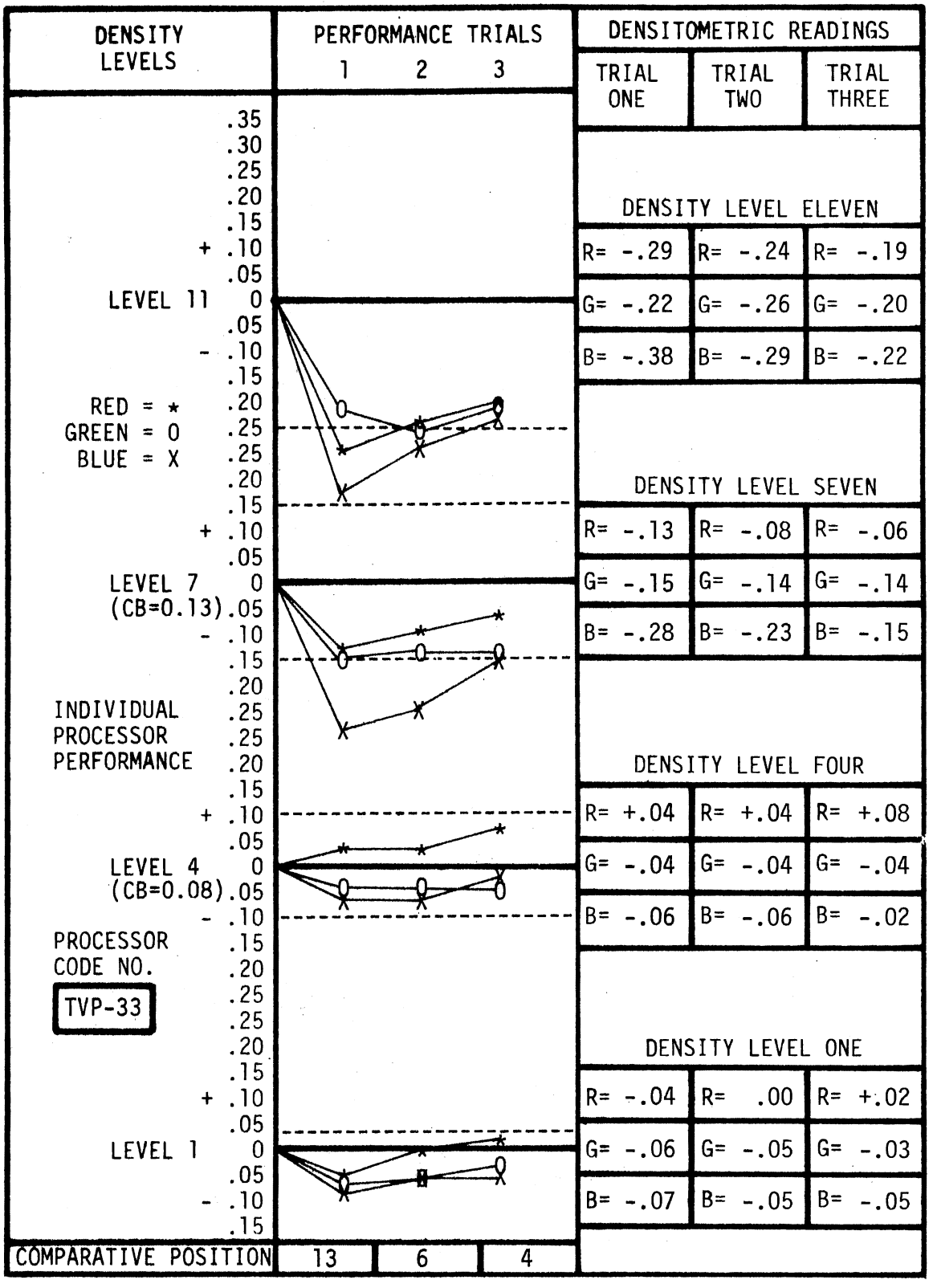


Figure 33. Individual Processor Performance, TVP-33

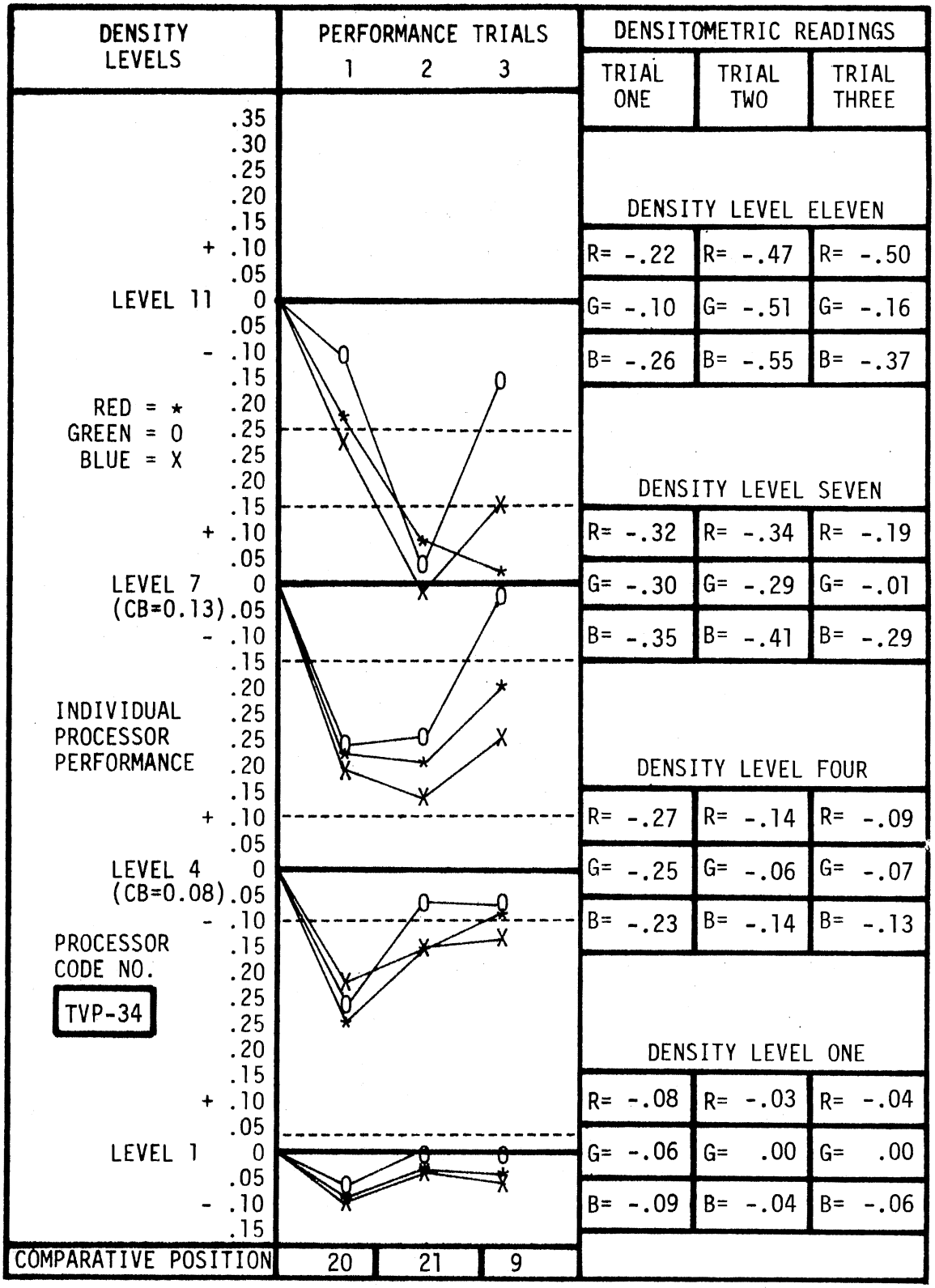


Figure 34. Individual Processor Performance, TVP-34

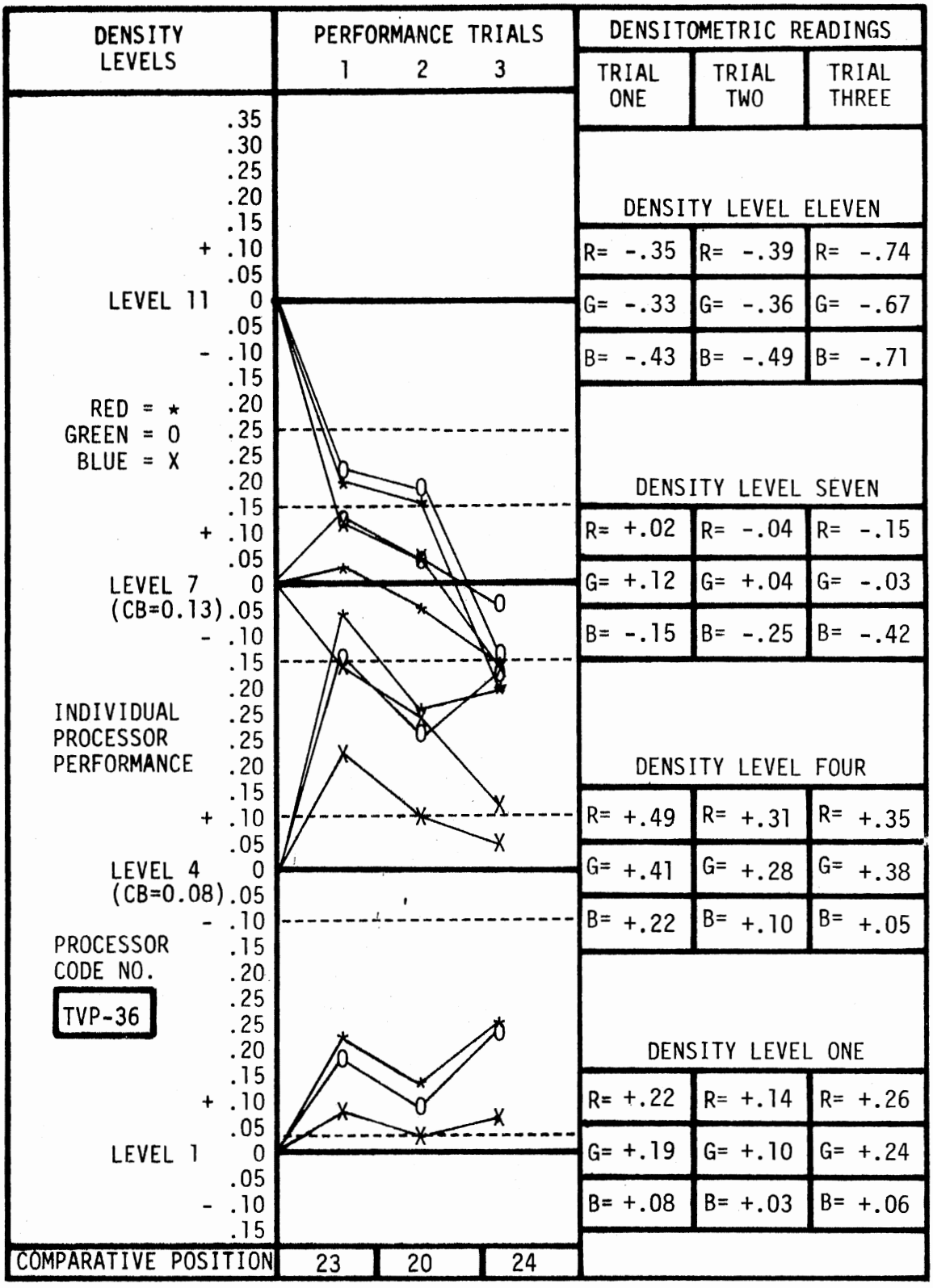


Figure 35. Individual Processor Performance, TVP-36

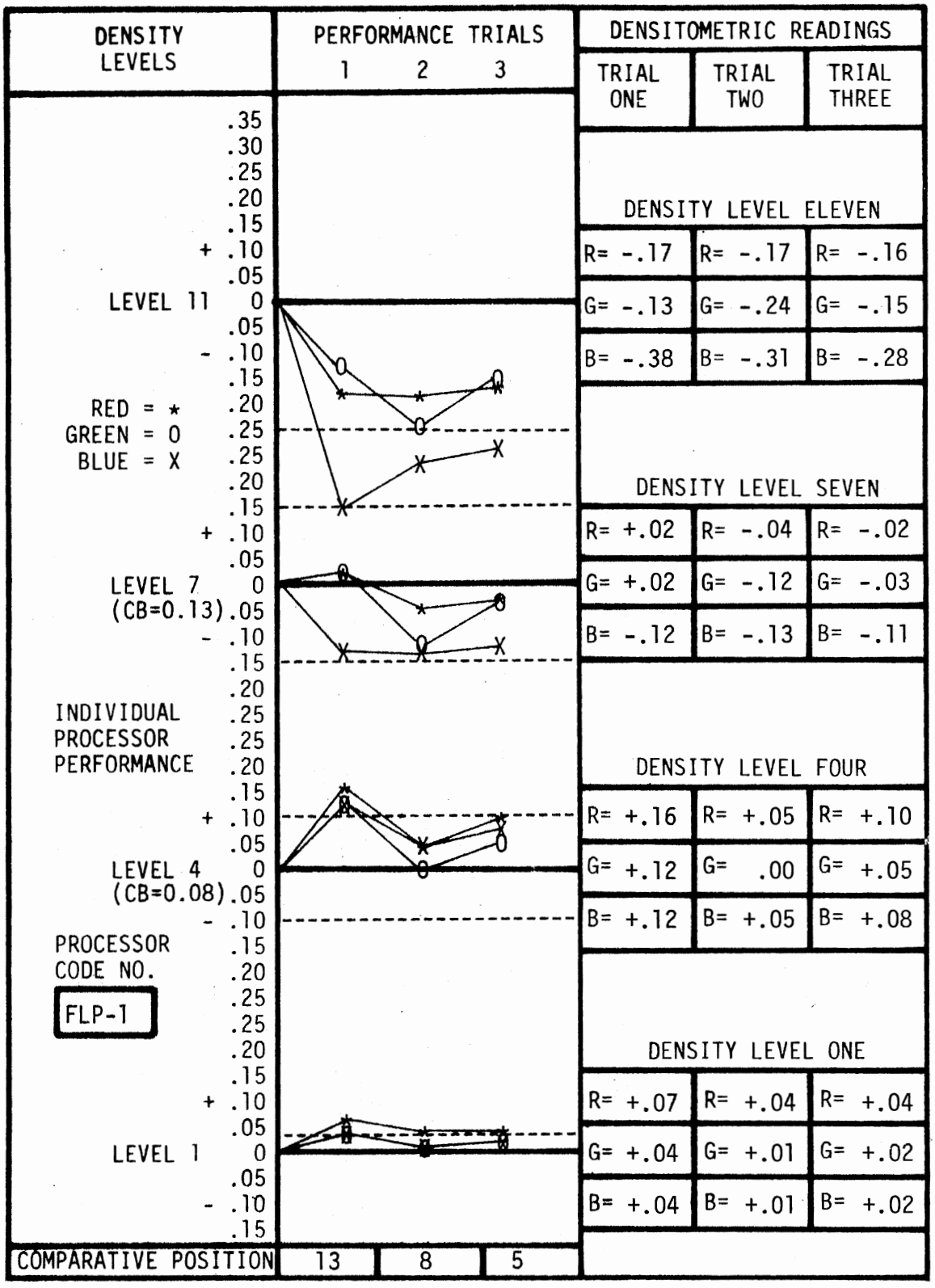


Figure 36. Individual Processor Performance, FLP-1

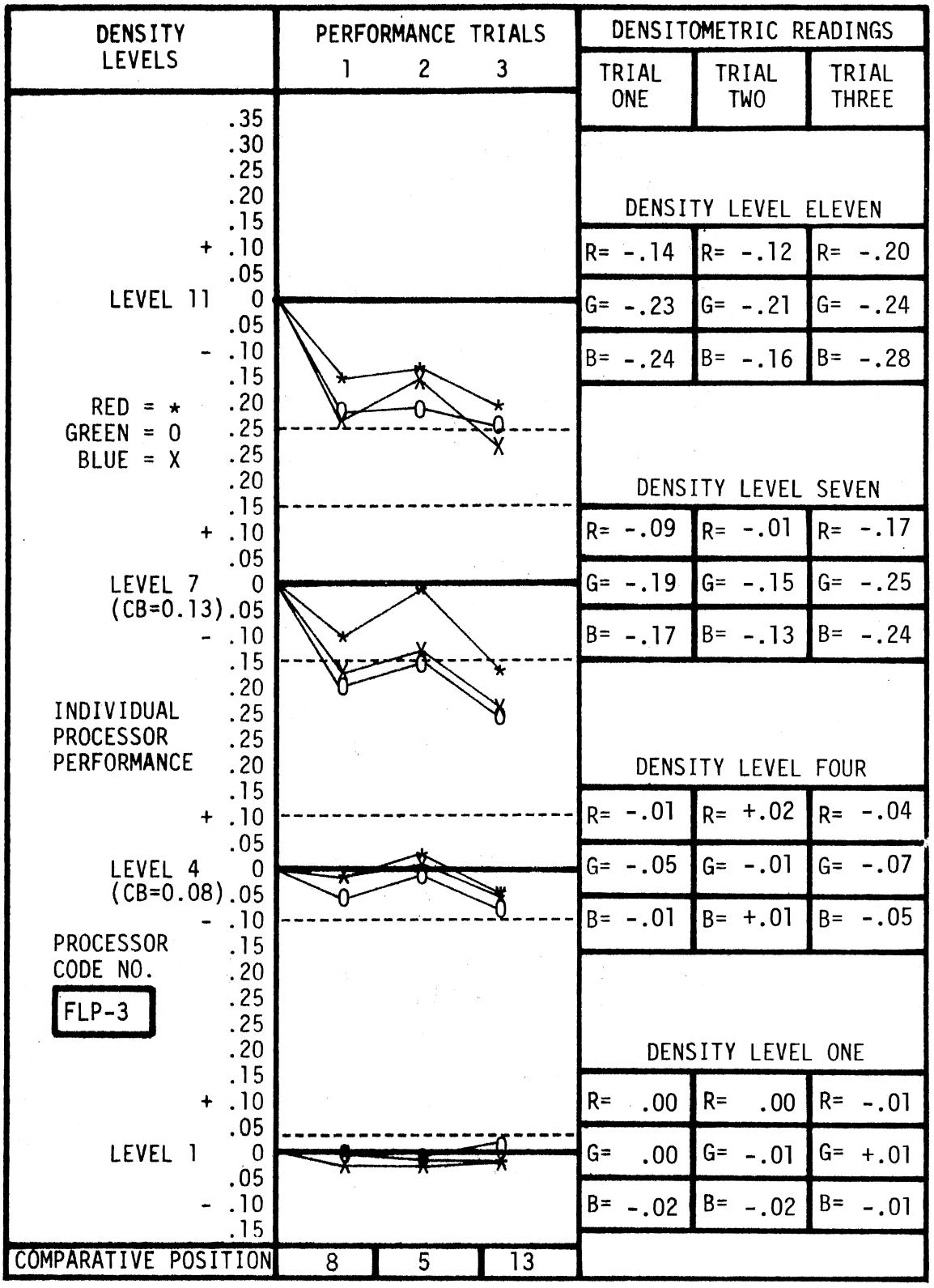


Figure 37. Individual Processor Performance, FLP-3

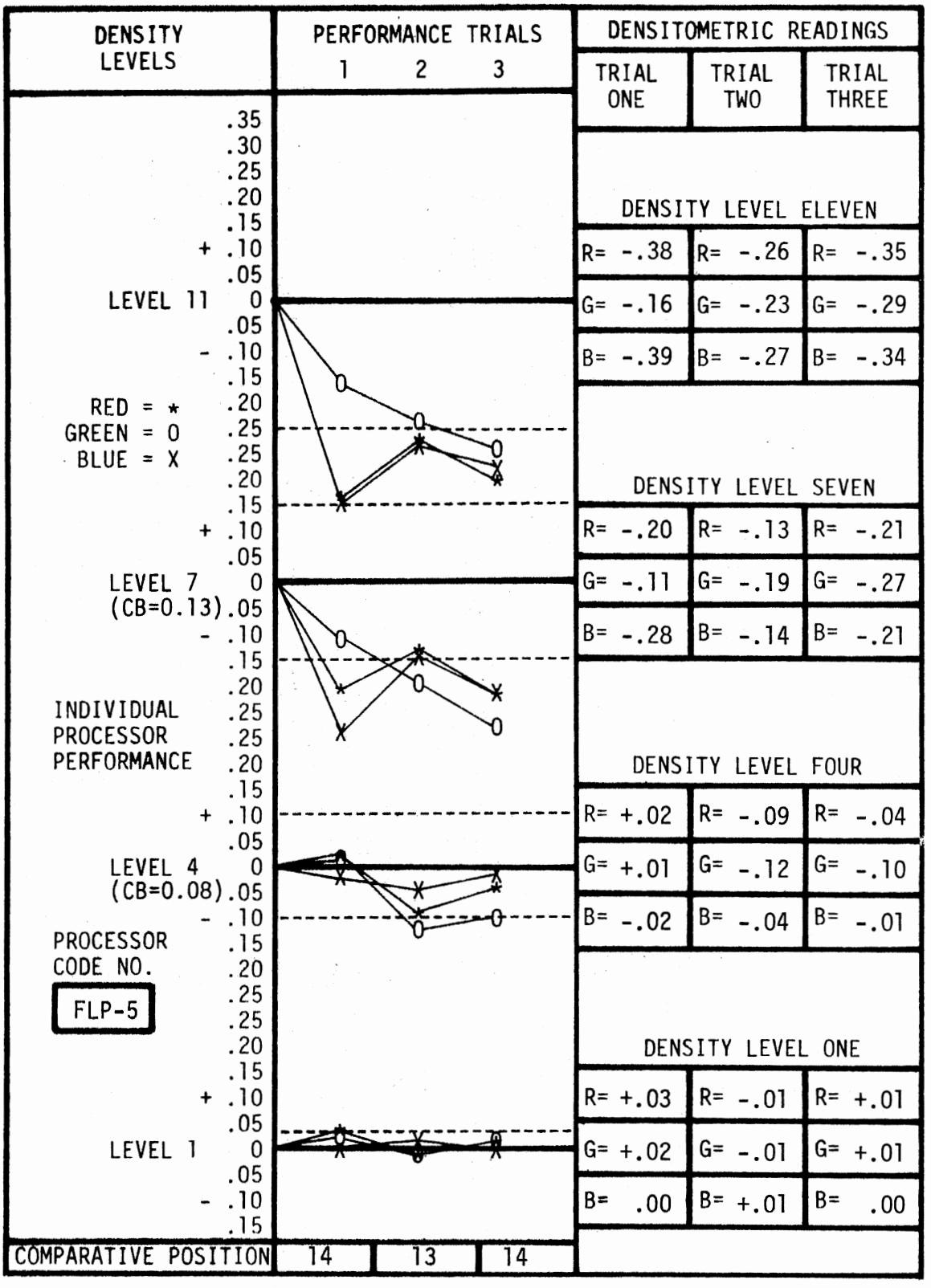


Figure 38. Individual Processor Performance, FLP-5

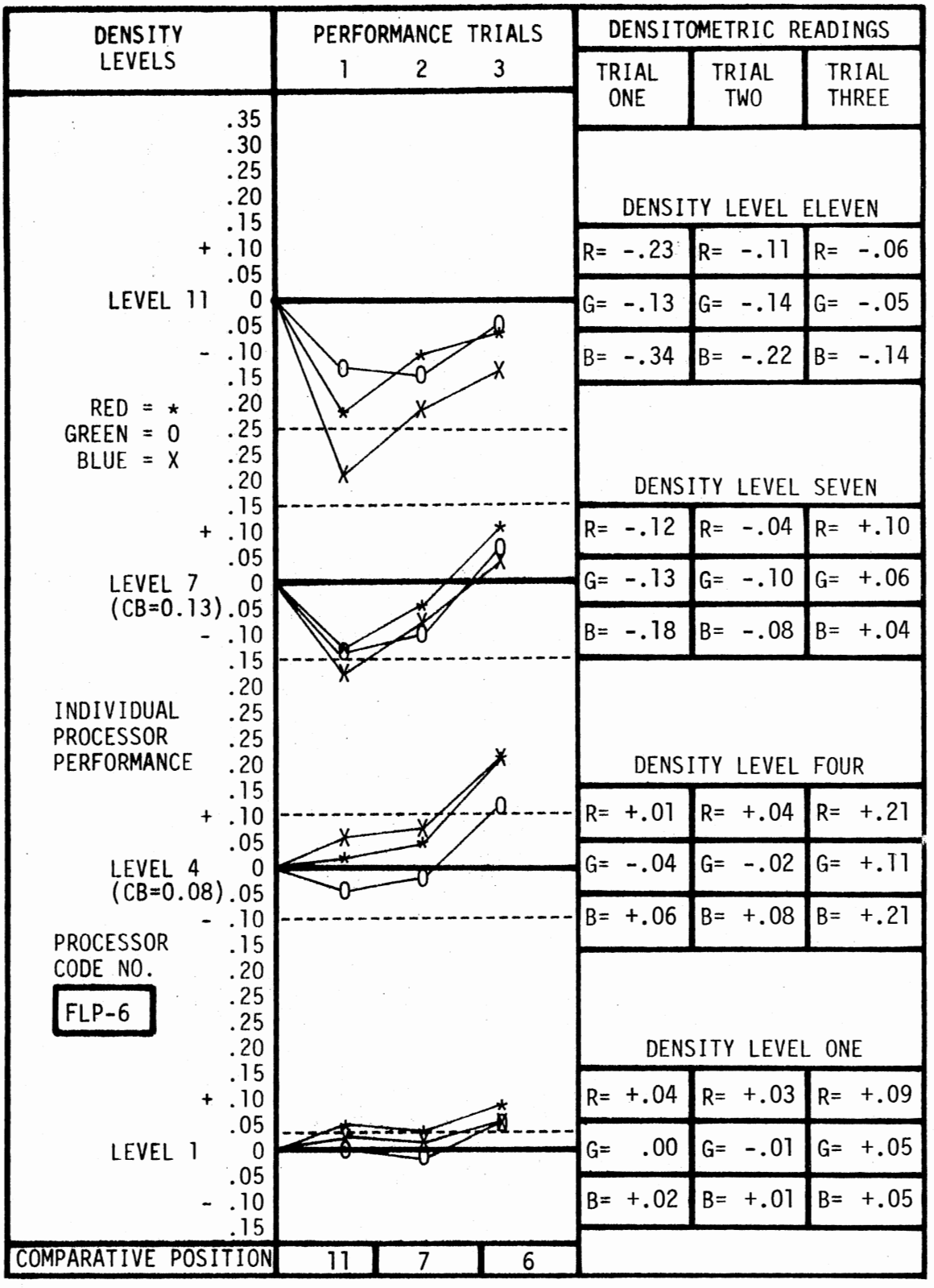


Figure 39. Individual Processor Performance, FLP-6

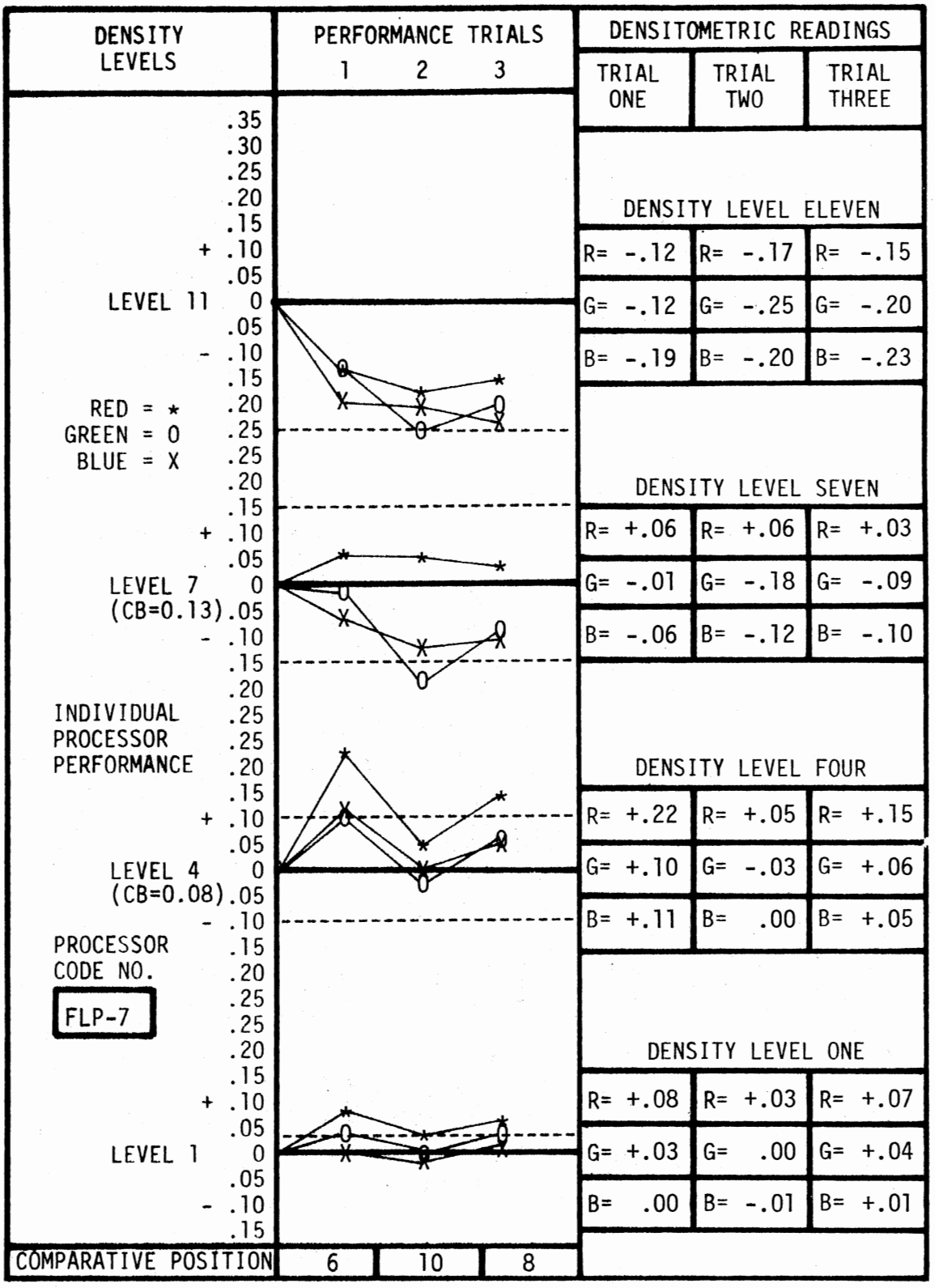


Figure 40. Individual Processor Performance, FLP-7

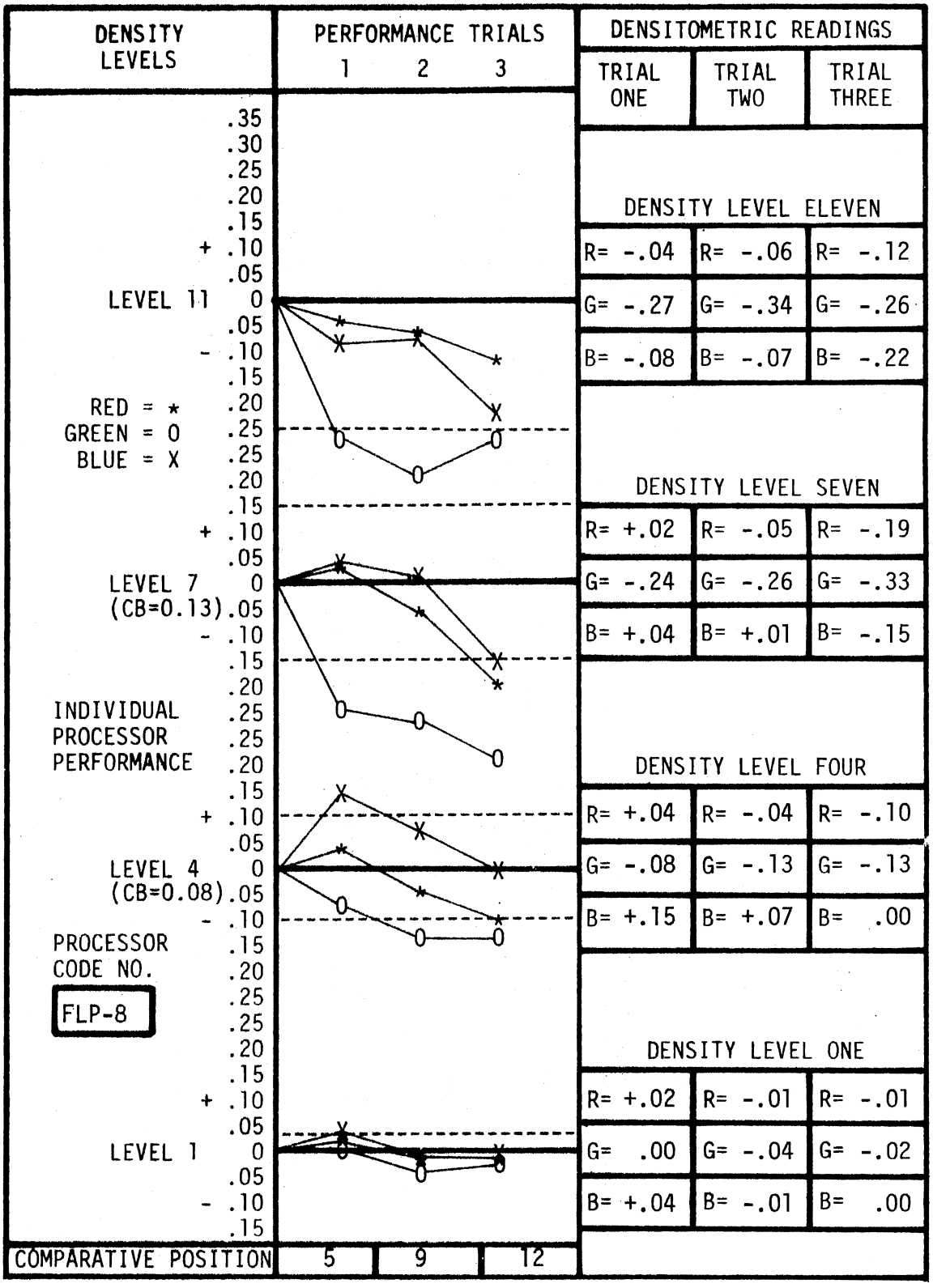


Figure 41. Individual Processor Performance, FLP-8

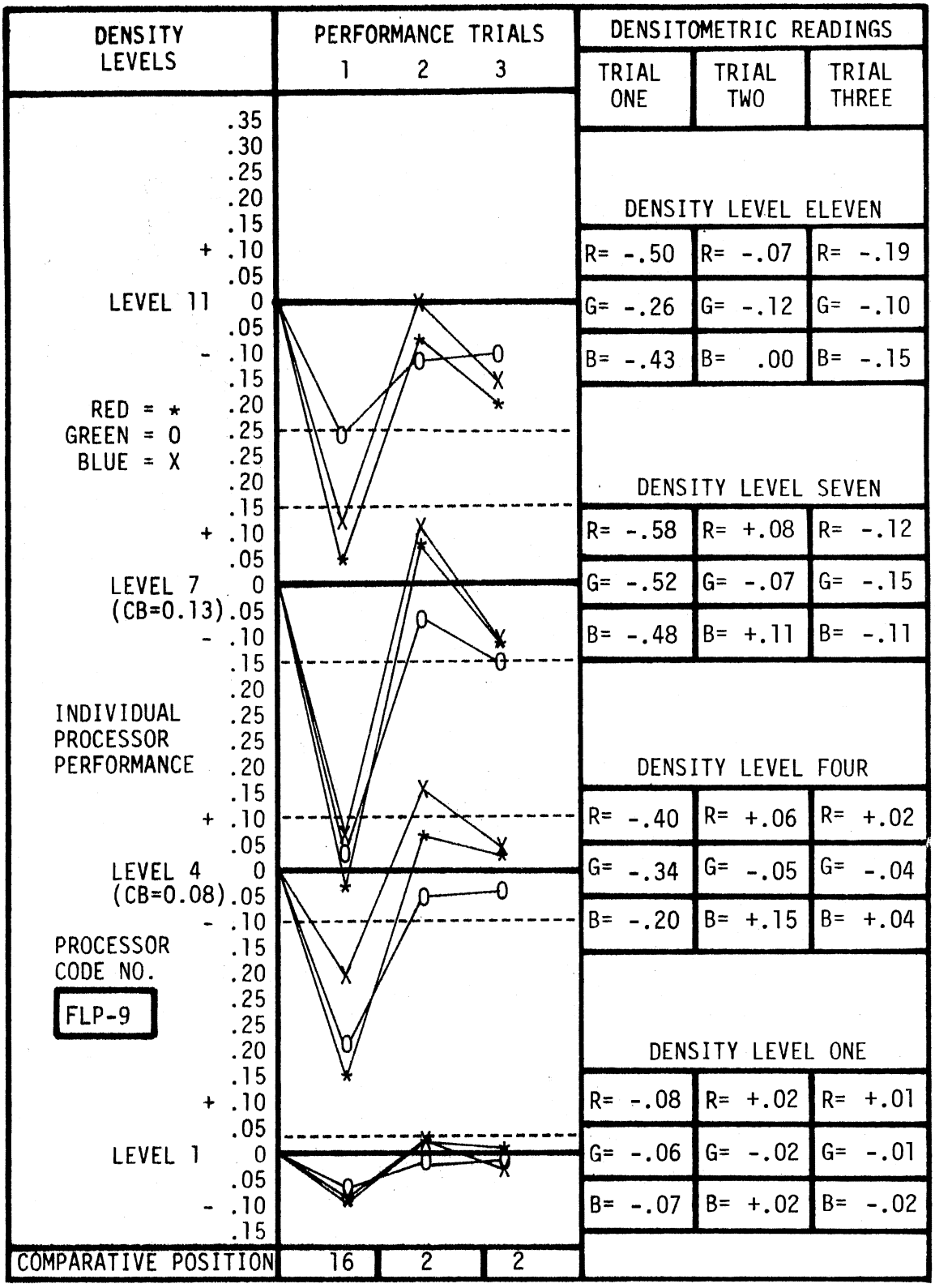


Figure 42. Individual Processor Performance, FLP-9

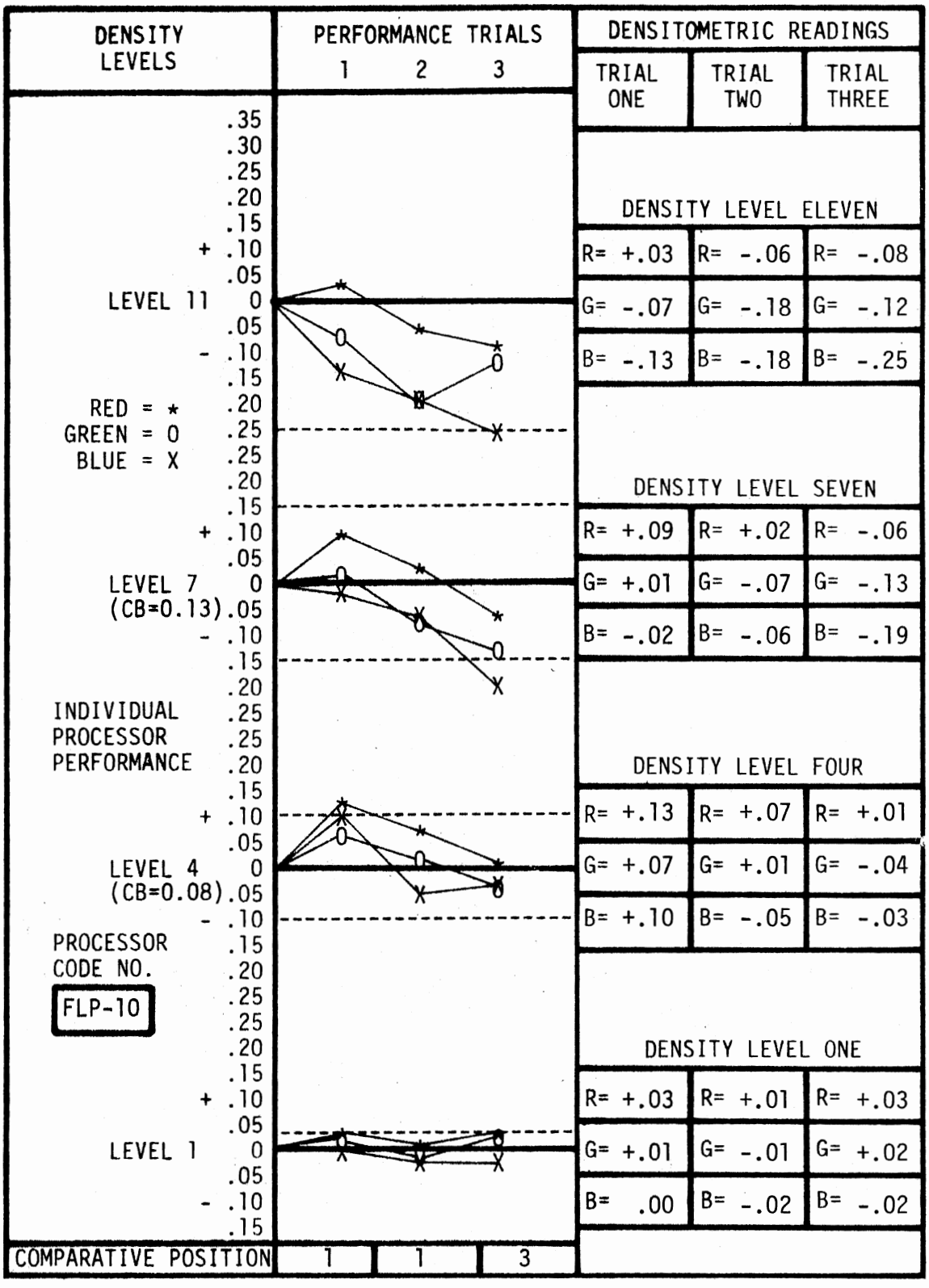


Figure 43. Individual Processor Performance, FLP-10

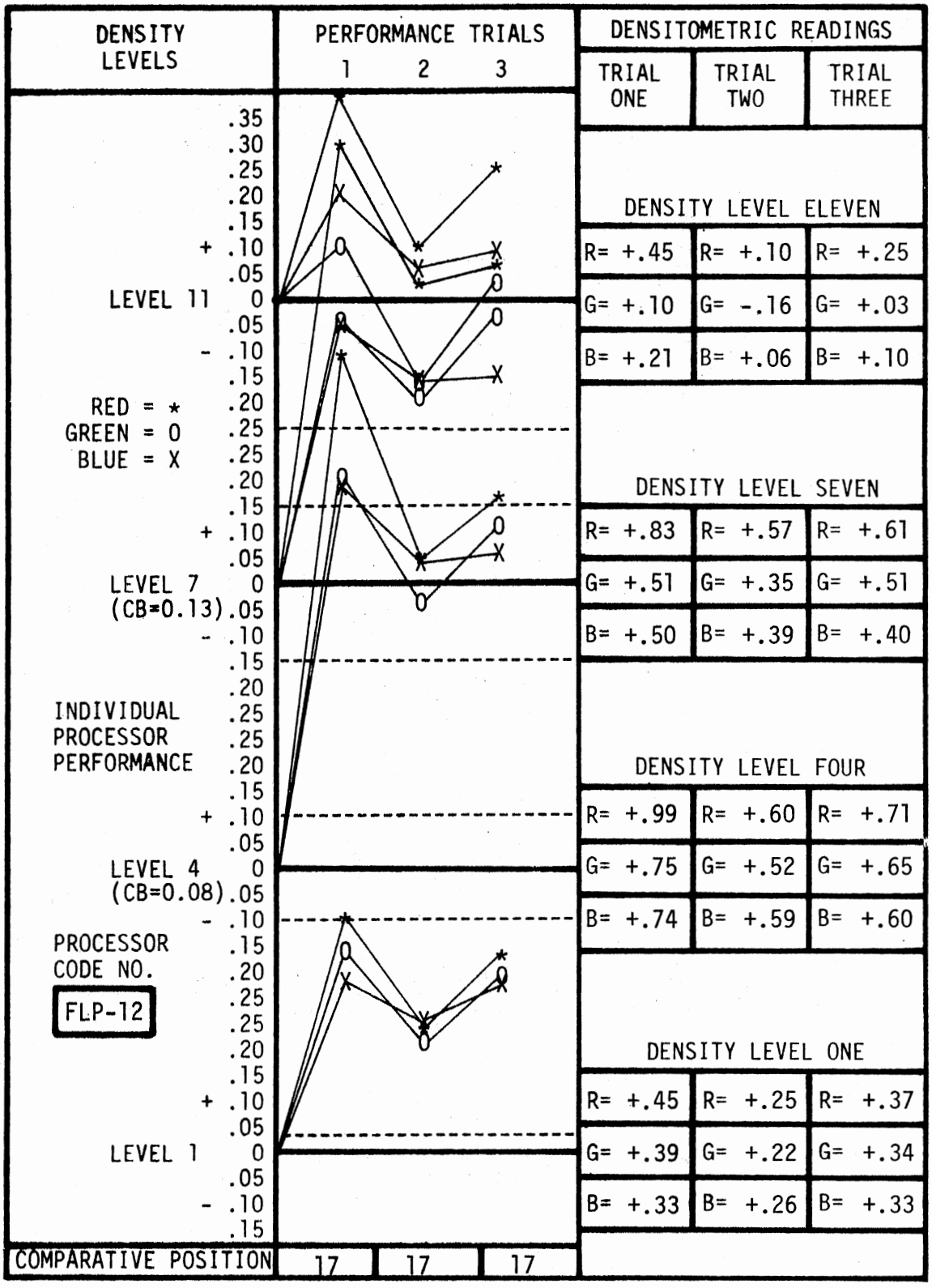


Figure 44. Individual Processor Performance, FLP-12

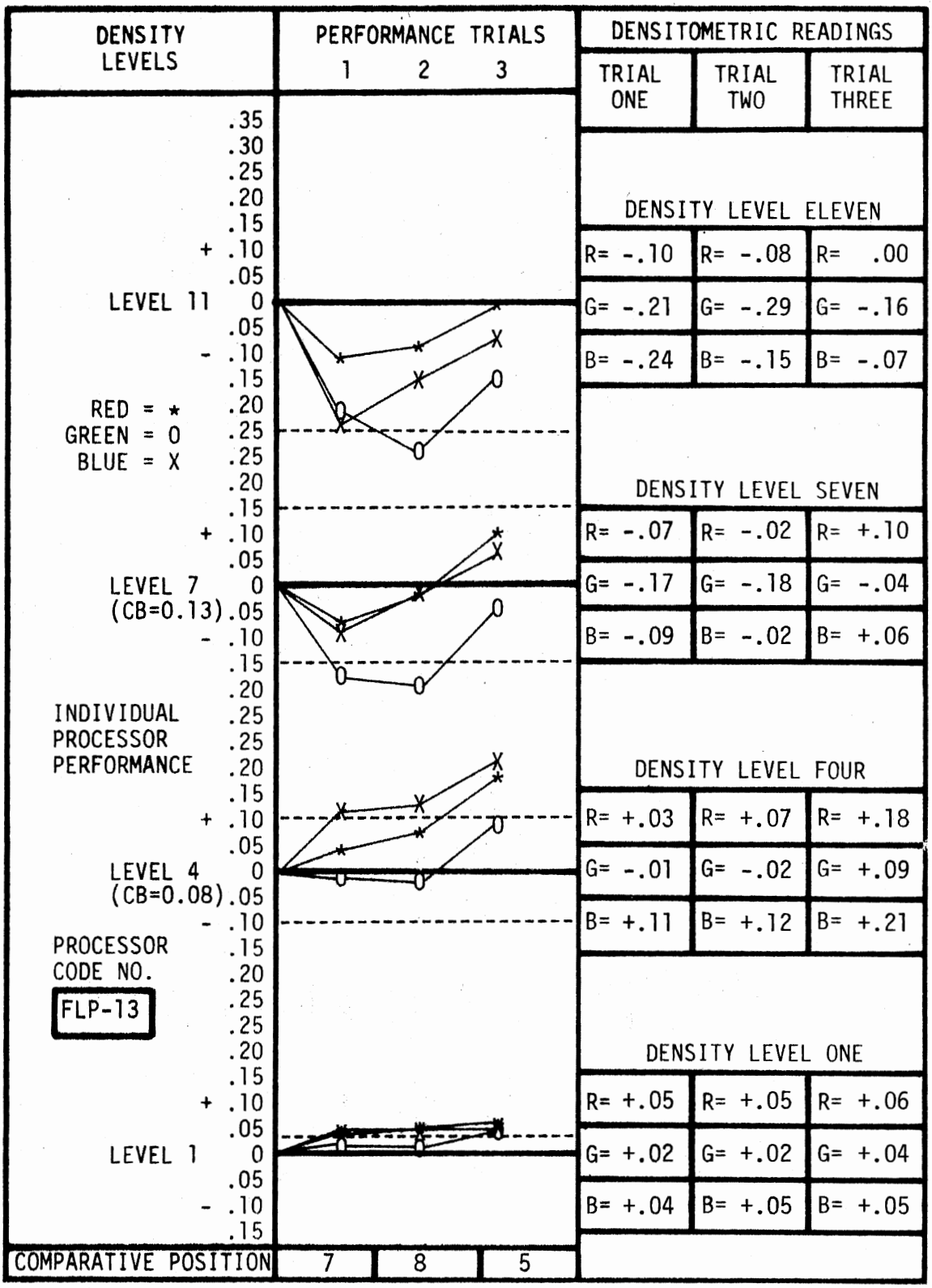


Figure 45. Individual Processor Performance, FLP-13

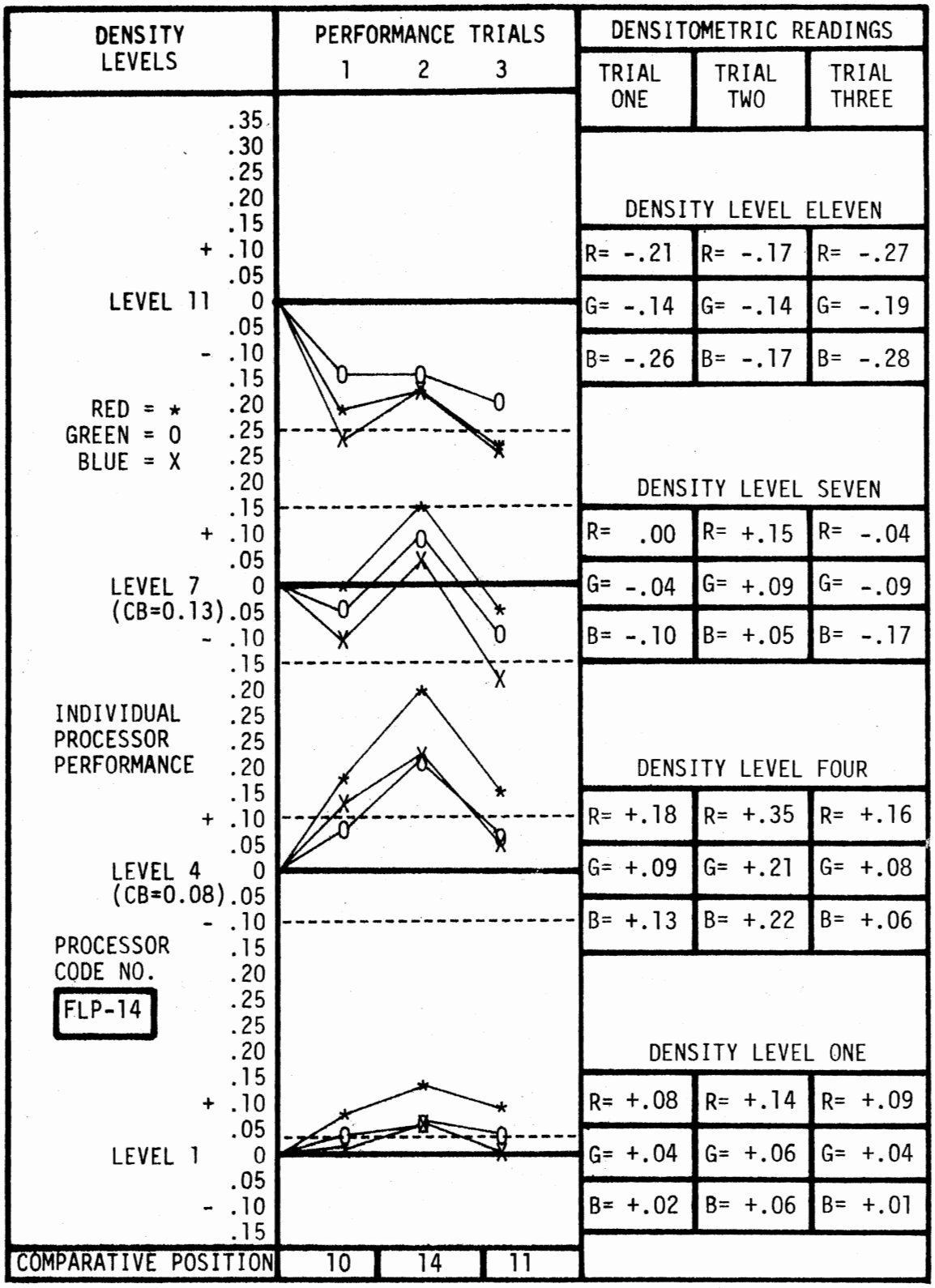


Figure 46. Individual Processor Performance, FLP-14

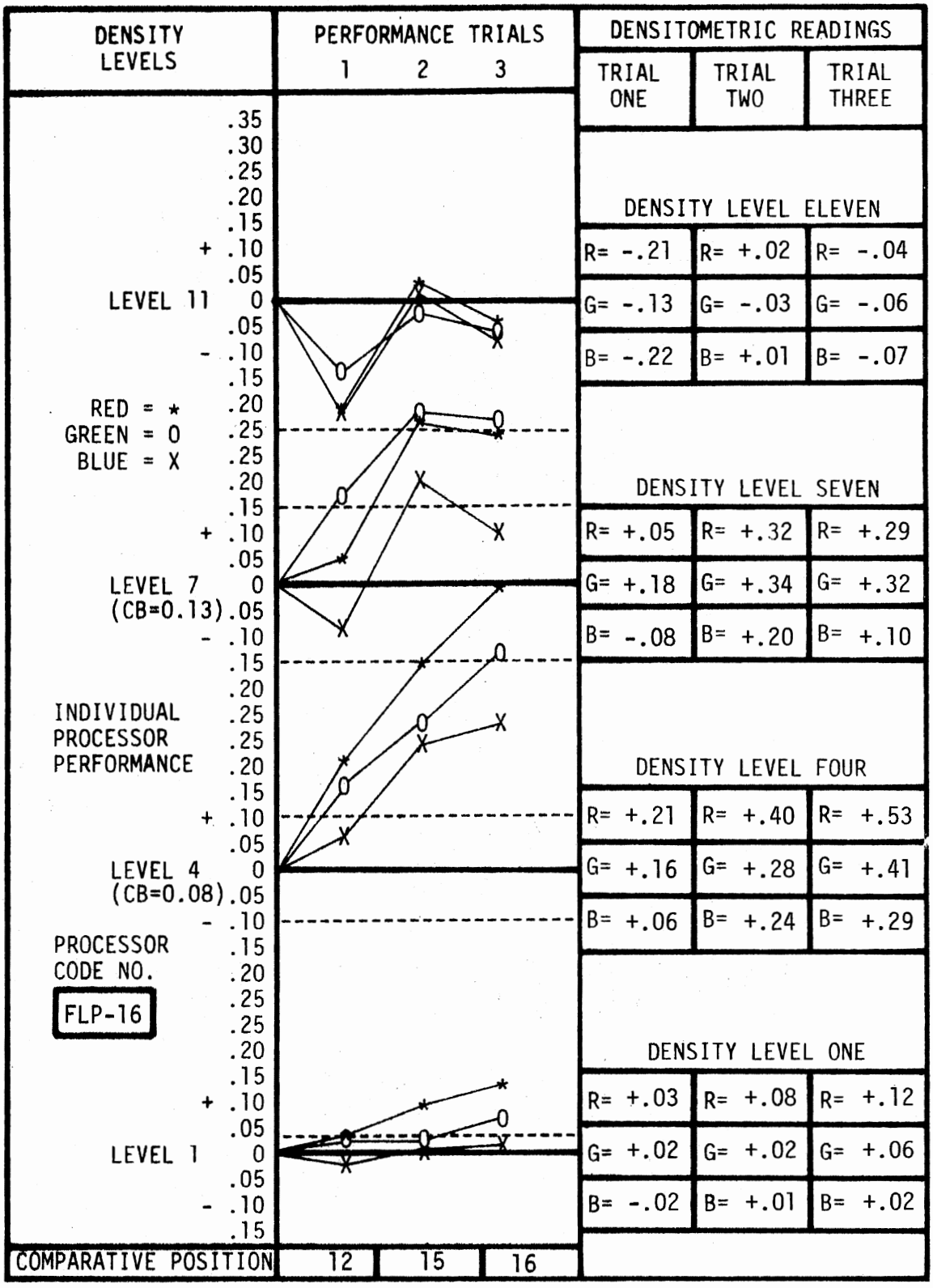


Figure 47. Individual Processor Performance, FLP-16

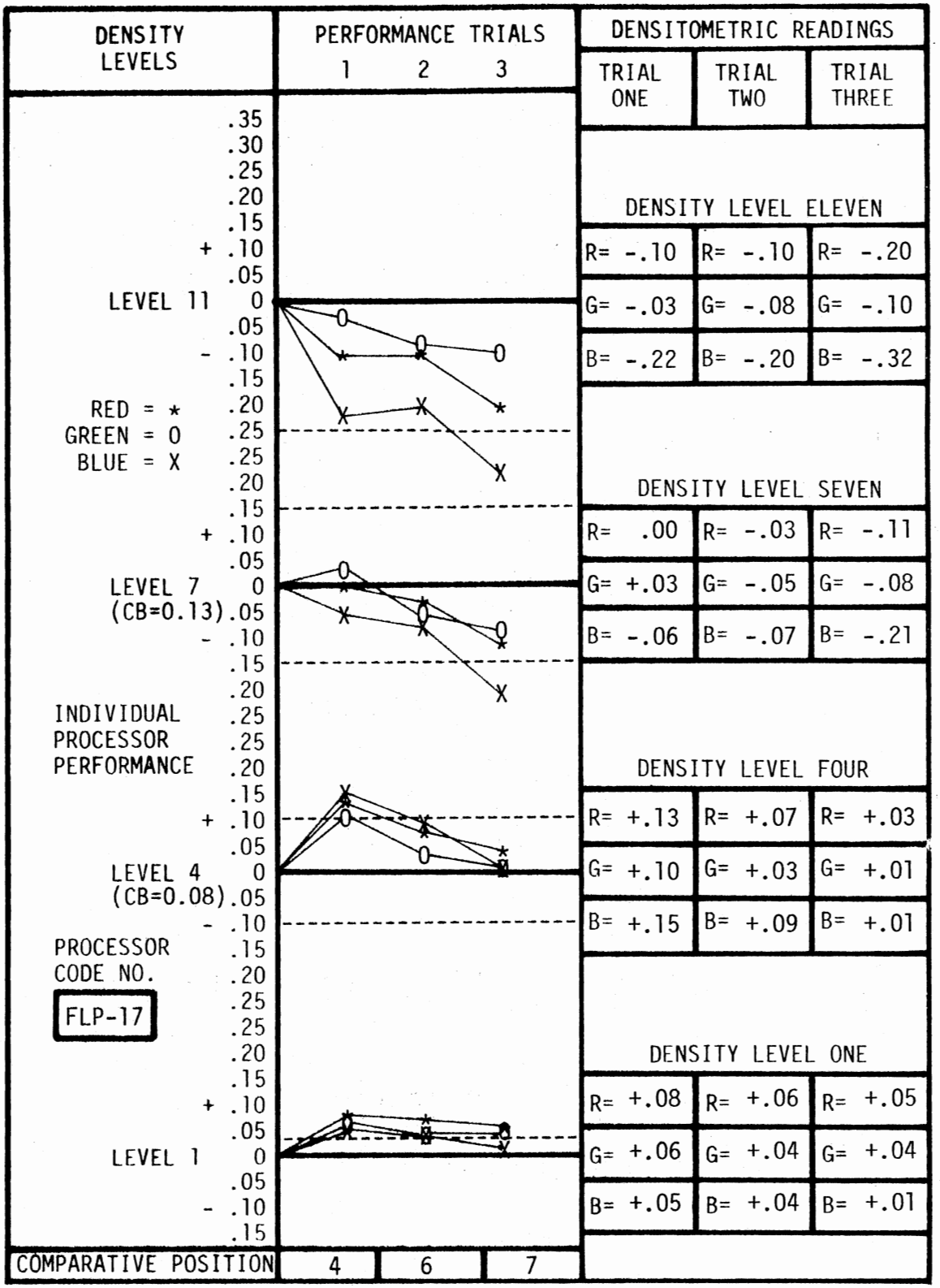


Figure 48. Individual Processor Performance, FLP-17

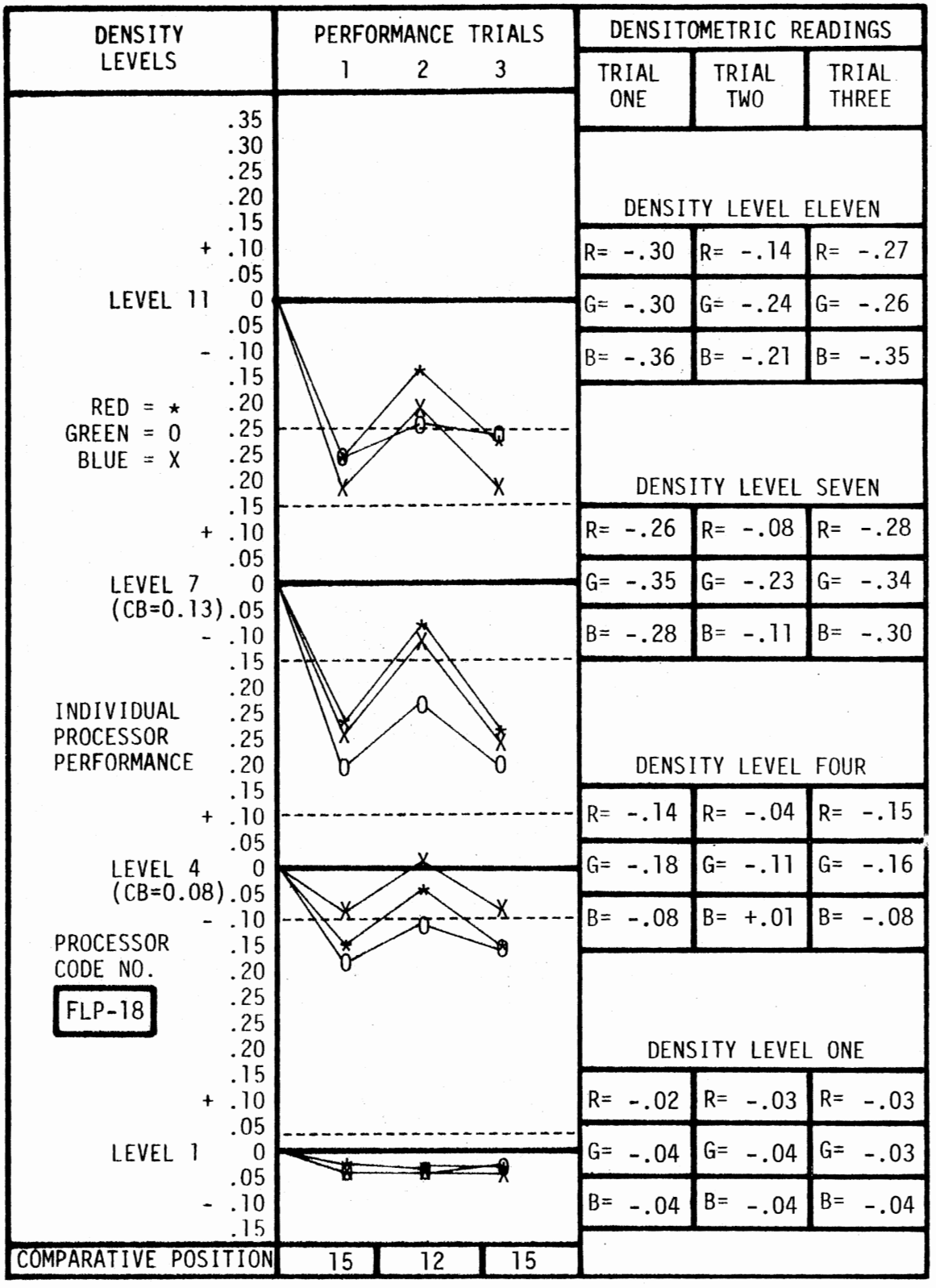


Figure 49. Individual Processor Performance, FLP-18

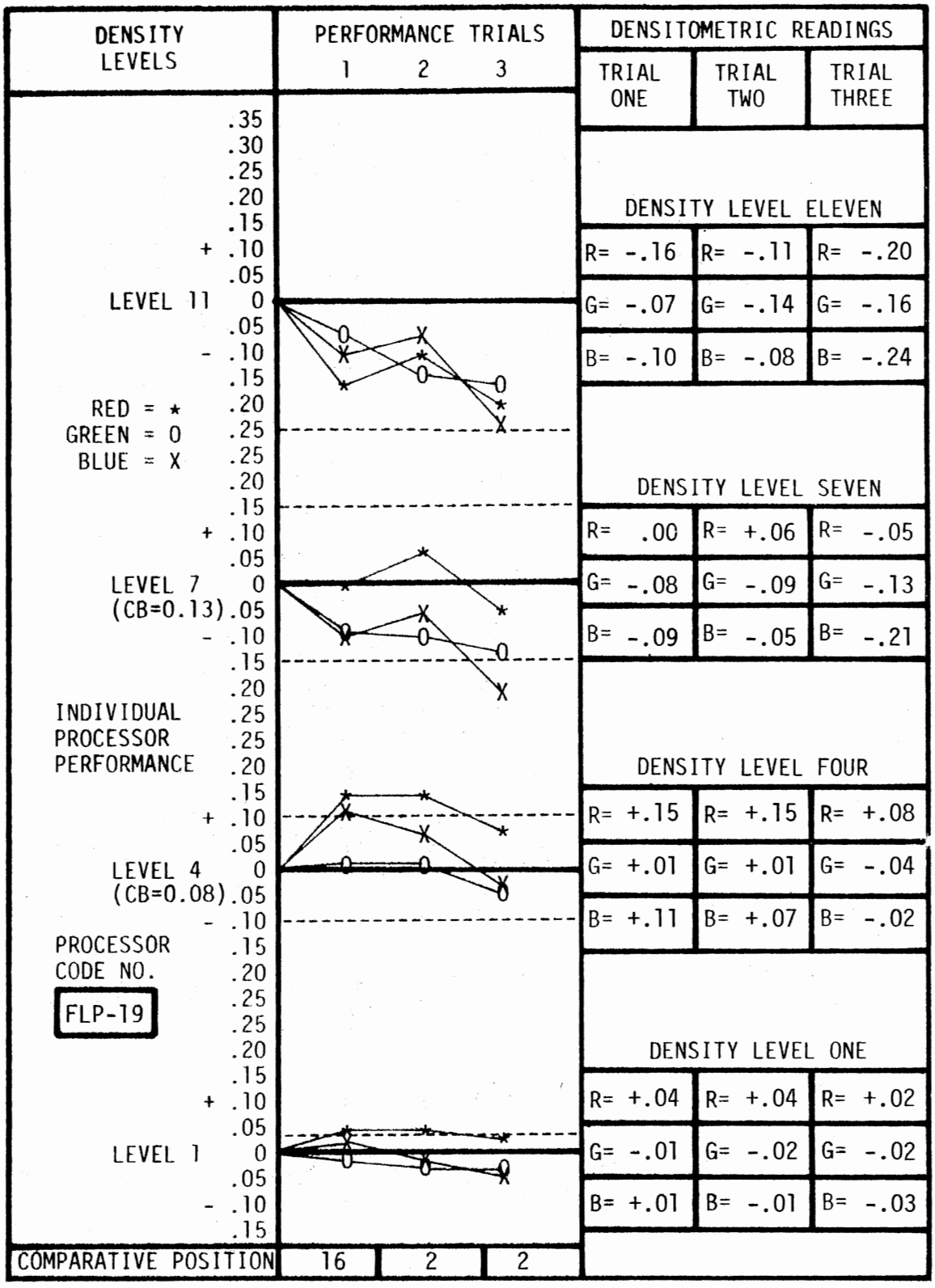


Figure 50. Individual Processor Performance, FLP-19

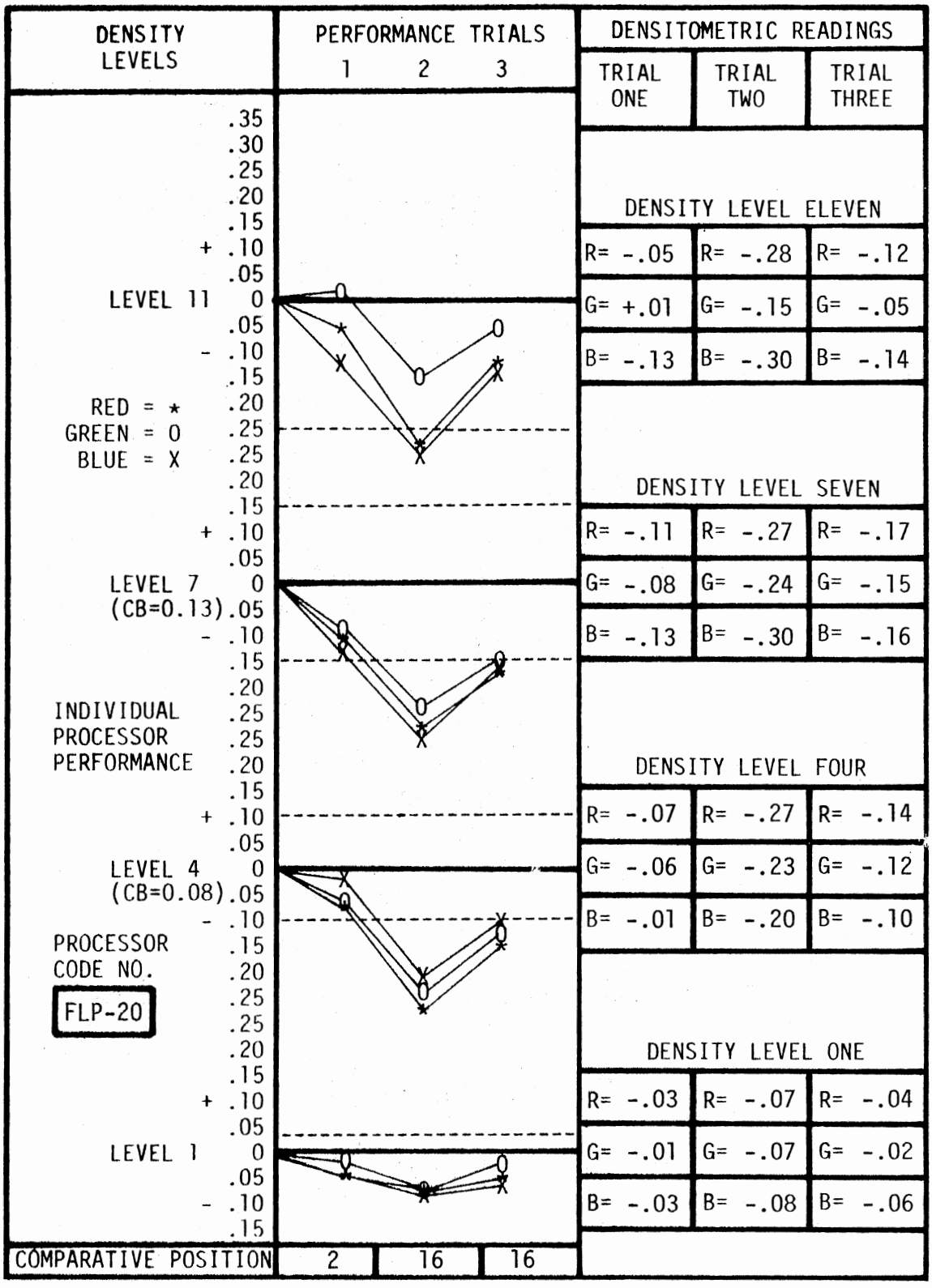


Figure 51. Individual Processor Performance, FLP-20

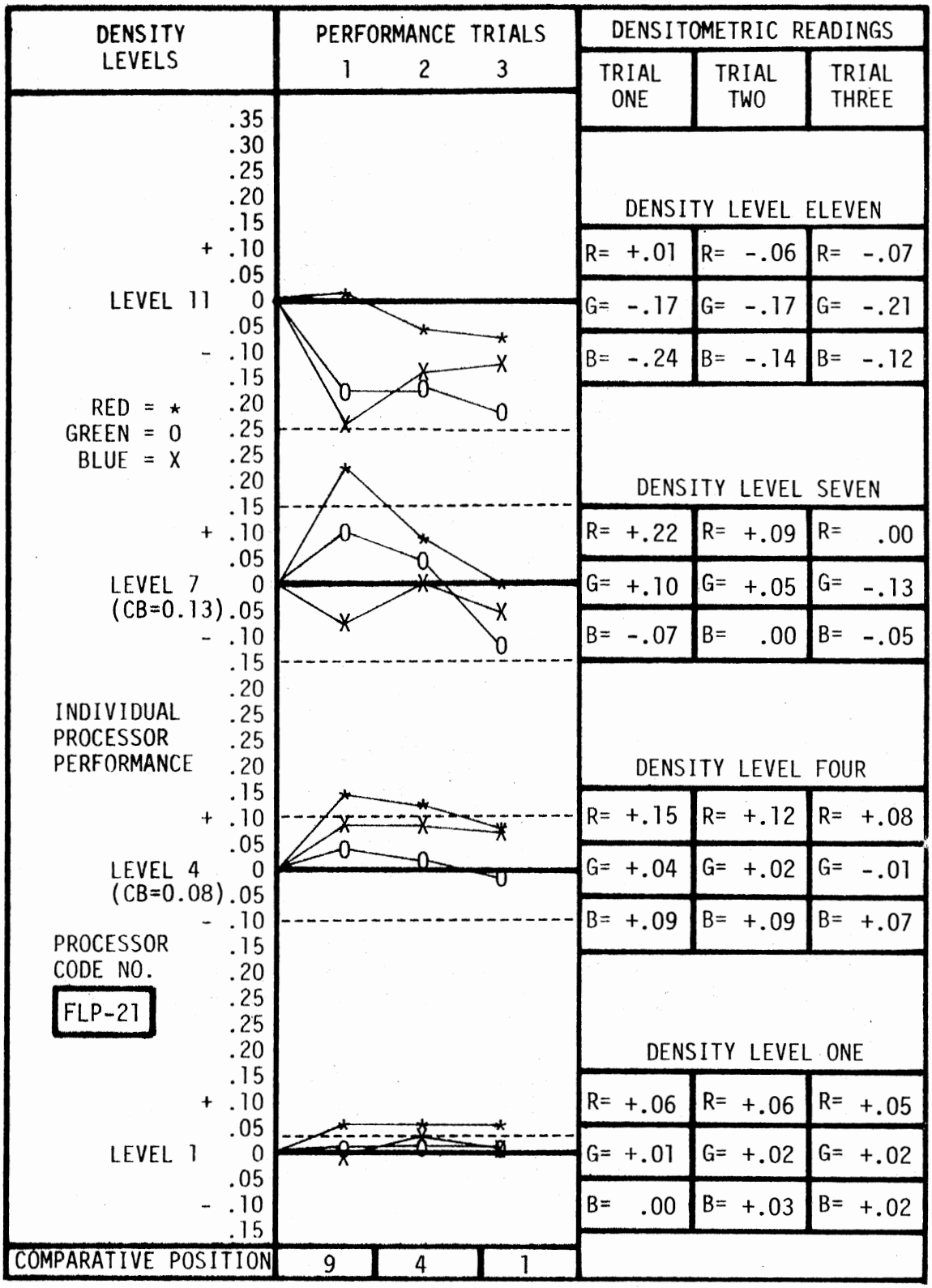


Figure 52. Individual Processor Performance, FLP-21

VITA[2]

Richard Verne Coup

Candidate for the Degree of

Doctor of Education

Thesis: A COMPARISON OF PROCESSING CONSISTENCY BETWEEN TELEVISION STATION PROCESSORS AND PROFESSIONAL FILM LABORATORIES AS MEASURED BY DENSITY AND COLOR CHARACTERISTICS OF VNF COLOR CONTROL STRIPS

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