DEVELOPMENT OF IMPROVED TECHNIQUES FOR BONE AND PARASITE REMOVAL IN ALASKAN WHITEFISH FILLET PRODUCTION

PHASE I FINAL REPORT

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EXECUTIVE SUMMARY:

Over the past decade the Alaskan seafood industry has evolved from an emphasizes on a few high valued species to include high volume low valued species. Along with this evolution have come problem associated with the processing and marketing of whitefish such as cod, pollock, and flatfish. A major processing problem which effects the whitefish industry worldwide is parasitic infection. As a result, parasite detection and removal processes must be carried out in order to maintain acceptable quality. The processor has a choice between allocating monetary resources towards labor and machinery for the detection operations or incurring product rejection losses due to low consumer acceptance.

In 1989 the Fishery Industrial Technology Center (FITC) received an Alaska Fishery Development Foundation grant, cooperative agreement NA-89-ABH-00008, to assess the effect of light intensity and wavelength on nematode detection efficiency during cod filleting operations. The primary objective of this study was to determine the optimum wavelength and light intensity which would enhance parasite and bone detection. The

second objective was to build a commercial scale table to test lighting conditions on a production basis. The final objective of this research was to develop a computer vision system to automate the detection process. Objectives two and three were contingent upon the results obtained from objective one.

The approach used in this study was to construct a one person trimming table with a variable intensity and wavelength light source. This table was then incorporated in a processing plant candling line and individual worker productivity and detection efficiency were monitored.

Observations and data were collected on 180 days between 2/17/90 and 2/21/91. During this time period over 16,000 fillets were examined. From these data, detection efficiency and productivity for eight trimmers at three processing plants were evaluated. Data for each trimmer were collected for both standard and experimental trimming tables.

Results indicate that worker productivity is directly related to an increase in intensity of incandescent white light. An analysis of hourly productivity; however, indicate that productivity at high light intensities may not be sustainable. Evaluation of the long term effects of exposure to high light intensities was beyond the scope of this investigation and, consequently, is not addressed in this analysis.

Data indicate no improvement in detection efficiency using optical detection techniques. These results and those of similar research indicate that optical techniques have limited potential for improving parasite detection efficiency. The lack of improvement in detection efficiency resulted in canceling the Phase II development of a prototype production table. These results also preclude the development of a machine vision system as proposed in Phase III of this project.

The proposed approach for this project was to monitor a complete series of intensities and wavelengths for each worker. This design was adopted to allow comparison of results between workers. However, this sampling design proved impractical during project implementation due to the instability of the processing work force. Several incomplete data sets were obtained when workers either left the plant for other employment or refused to continue participation in the project.

The major reason workers changed employment was uncertain work schedules due to erratic processing resulting fishery closures and market demands. Workers who refused to continue participation in the project had the perception that the aim of the project was other than the stated goals (i.e., worker performance was being evaluated by the company).

Completion of the project required a longer period of time than originally anticipated. This was mainly due to intermittent data collection resulting from erratic processing schedules.

Several factors contributed to this problem. A major factor was the sporadic availability of cod which was a consequence of periodic cod trawl closures resulting from halibut by-catch. An additional factor was market demands for cod fillets. During the sampling period a large percentage of cod landed were headed and gutted or frozen in the round. These problems interrupted the sampling schedule and resulted in discarding data sets or an extended wait to complete data sets.

The rate of detection efficiency was calculated from the data for different intensities and wavelengths. The size of the candling surface on the experimental table only allowed an area approximately 2 feet by 1 foot that could be illuminated from underneath. Therefore varying sizes of the lighted surface for optimum detection efficiency was not applicable to this project. A machine vision system was not developed due to unforeseen lack of resources and time.

INTRODUCTION

Whitefish have been the basis of productive foreign and domestic fisheries in Alaskan waters since 1962. U.S. fishermen did not participate extensively in these fisheries until after the passage of the Magnuson Fishery Conservation and Management Act in 1976 and the collapse of the king crab fishery in the early 1980's. Alaska whitefish have since become a major U.S. fishery with the current Bering Sea and Gulf of Alaska TAC set at 2.3 million metric tons.

Commercially important whitefish resources in Alaskan waters consist primarily of walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), rex sole (*Glytocephalus zachirus*), yellowfin sole (*Limanda aspera*), Dover sole (*Microstomus pacificus*), rock sole (*Lepidopsetta bilineata*), and flathead sole (*Hippoglossoides elassodon*) (Hughes and Parks, 1975). Additionally, sablefish (*Anoplopoma fimbra*), and arrowtooth flounder (*Atheresthes stomias*) are important resources in the Gulf of Alaska (Morris et al. 1983).

Whitefish are susceptible to infection by a number of parasites including protozoa, trematodes, nematodes, and cestodes (Arthur, 1984; Olson, 1986). The occurrence of parasites in commercial species of marine fishes has been a long standing concern for the fishing industry (Agersborg, 1918; Jackson et al., 1978; Myers, 1976). Of particular concern to Alaska's industry is the presence of nematodes in cod fillets. Although the majority are removed by washing, trimming, and evisceration, many nematodes remain undetected and are passed on to consumers. Visual inspection, even aided by candling, is unable to detect deeply embedded parasites. It is estimated that only 60-70% of nematodes in heavily infested fish are removed by current techniques.

Larvae of two species of the nematode family Anisakidae are commonly found in cod fillets, the "seal or cod worm" (*Phocanema decipiens*) and the "herring worm" (*Anisakis simplex*). The two species are similar in appearance and infest both the viscera and musculature of the host. Larvae *A. simplex* are from 9 to 36 mm long, off-white and form coiled cysts within the muscle tissue. Larvae *P. decipiens* range in size from 9 to 58 mm, vary in color (creamy white, yellow, brown, reddish brown), and entwine irregularly in the musculature. Olson and Landkamer (1985) found infestations of *A. simplex* in 100% and *P. decipiens* in 90.9% of *Gadus macrocephalus* examined. Infestations of *A. simplex* were concentrated in the anterior and posterior ventral portions of the fillet. *Phocanema decipiens*, however, were not concentrated in particular regions but were evenly distributed throughout the musculature.

Parasite infection can render host fish unmarketable for reasons of human health and aesthetics (Arthur et al., 1983; Cheng, 1973; Chitwood, 1970). The presence of nematode worms in cod fillets makes the product unacceptable and may result in rejection of an entire lot by wholesalers, degradation of existing markets, and impact current consumer trends toward fish products. Although industry standards vary, the allowable limit of parasites and bones is one to three per 15 pounds of packaged product. The U.S. defect action level limits the number of parasitic cysts to 50 per 100 pounds, when at least 20 percent of the examined fish are infested (Valdimarsson et al., 1985).

Nematode parasites may survive in raw fish flesh for several days, but are killed when heated to temperatures of 70° C for 7 minutes or when frozen to -20^0 C for 24 hours (Valdimarsson et al., 1985). Olson (1986), indicates that nematode larvae are killed after only 1 minute exposure at 60^0 C. Margolis (1977) described a number of cases of nematode infestation (Phocanemiasis) in humans. The majority of cases described were due to parasite penetration of the gut. Human infestation generally was the result of eating partially cooked infected cod. Properly cooked or frozen fish, consequently, may not present a human health hazard. The recent popularity of sushi and sashimi type products, however, represent a potential for human infection. Unquestionably, the aesthetics and marketability of fish products are severely impacted by the presence of nematodes.

The level of whitefish harvest off Alaska and evidence that piscine parasites may result in human infestation have stimulated a greater interest in parasite removal. The detection and removal of parasites during processing is a major expense to the seafood industry; however, is critical to maintaining product quality. The processor has a choice between allocating monetary resources towards labor and machinery for detection and removal operations or incurring product rejection losses due to low consumer acceptance. The current method of detecting parasites is by candling, which involves inspecting each fillet over a translucent surface illuminated by fluorescent light. Workers detect parasites as they trim each fillets of defects, bones, and undesired flesh. Parasites are then removed manually, and in most processing plants, trimmed fillets are re-inspected for bones and parasites by quality control workers.

The candling process is labor intensive and costs between $.21 to $.35 per pound of product, approximately 50% of production costs. Candling is also the limiting factor for production levels at seafood processing plants. At lower production rates, there is a higher potential for fillets to be exposed to warm temperatures prior to freezing. Processing delays may, consequently, produce a lower quality product due to microbial growth and enzymatic biodegradation.

APPROACH:

Observations and data collection extended from 2/17/90 to 2/21/91. Data were collected on 180 days during this time period with an excess of 16,000 fillets observed. Three trimmers (A, E and F) were observed at processing Plant I; three (DD, EE, and GG) at processing plant II; and one trimmer (C) at processing plant III. With the exception of trimmer F, for which two data sets were obtained, data were collected for only a single wavelength from each trimmer. An average of 2,000 fillets were observed for each color-worker combination. Another 1,000 observations represented incomplete data sets and were not used in data analysis.

The experimental trimming table consisted of a fillet candling surface and a variable intensity incandescent spotlight enclosed within a metal box frame. The lighted candling area measures 30.5 c.m X 15.0 c.m. and the trimming surface top measures 70.5 c.m. X 30.5 c.m. Spotlight intensity was controlled with a rheostat and ranged from 0 to 8000 foot-candles. A cooling fan was installed inside the table to maintain candling surface temperature.

A Gossen light meter was used to determine light intensities of the experimental and standard candling surfaces. Light intensities were measured centrally on the candling surfaces. Standard table intensities ranged from 350 to 500 foot-candles, varying with different processing plants, table location and day.

Lee Colortran Inc. theatrical gels inserted in a holder on the spotlight were used to vary light wavelength. Wavelengths utilized were unanimously selected by processing workers, and FITC faculty as those which best enhanced the contrast between defects and fish flesh. Theatrical gels for which complete data sets were obtained include #107 (light rose), #110 (middle rose), #117 (steel blue), #138 (pale green), #152 (pale gold), #153 (pale salmon) and #202 (blue). In addition, a complete data set for unfiltered incandescent white light was also obtained. Data sets for gels #204 (full C.T. orange) and #205 (half C.T. orange) were incomplete, and were not utilized in data analysis.

Existing trimming tables at each of the three participating processing plants were used as standard tables. These tables consisted of several sections combined to form trimming tables of varying lengths. Each section consisted of a translucent surface approximately 30 cm wide and 170 cm long illuminated by two 60-watt white fluorescent tubes. Each section generally served as two work stations. The experimental table was set up as an extension of the existing candling tables in each plant to as closely as possible simulate normal working conditions.

Trimmers were selected by the plant processing floor managers and were requested to stay with the experiment throughout the duration. The most experienced trimmers were selected to minimize adjustment to the experimental procedure. Even though experienced trimmers were used, a time period was required for each trimmer to adjust to the experimental set-up and develop a routine. To compensate for this adjustment, data from the first day of sampling for each trimmer and table were not included in the analysis. This procedure was also followed after extended periods during which no sampling was conducted.

Light intensities of 500, 1000, 2000, and 8000 foot-candles (fc) for each trimmer and wavelength were tested. In three cases an intensity of 500 fc was not tested on the experimental table. This intensity was eliminated because of a lack of time and availability of workers. Data for some intensities were collected during relatively short time periods. These data are the result of processing schedules or a change in type of product processed during data collection (e.g., changing from fillets to headed and gutted during a processing run).

Data were collected on the experimental and standard tables simultaneously. At the beginning of each session, a trimmer was selected to candle at the experimental table and another at the standard table. Trimmers were supplied with baskets of fillets to trim. Each trimmer reported the number of parasites removed as each fillet was trimmed. Most trimmers verbalized the number; however, occasionally, a worker would hold up fingers to indicate the number detected. The start and end times for each basket trimmed were recorded. Trimmed fillets were placed into a separate basket and each basket was weighed to the nearest 10th of a pound. The number of fillets trimmed per basket were also recorded.

A minimum of 10 random samples from both the experimental and standard tables were collected for each ten baskets trimmed. These samples were sliced into thin sections to determine the number of parasites remaining after candling. A total of 1,098 fillets were randomly sampled and sliced for this quality check. Because these fillets were destroyed, processors requested that the number of fillets checked for parasites be kept to a minimum.

Worker productivity was determined as the weight of product processed per unit time. Productivity was analyzed with varying intensities and time of day. Detection efficiency was determined as the percentage of parasites detected. Productivity and detection efficiency were evaluated relative to performance on the standard table for each wavelength-intensity combination using a one-way ANOVA. Significant differences were then evaluated using a Tukey comparison of means.

FINDINGS:

BONE DETECTION:

During Phase I sampling, 1600 fillets from both the experimental and standard table were examined to determine bone removal efficiency. Only one bone was detected in those fillets examined. It was concluded, therefore, that trimming techniques being utilized were adequate for bone removal.

WORKER PRODUCTIVITY vs. LIGHT INTENSITY:

Analysis of individual worker productivity (in pounds per minute) on the experimental table compared to the standard table showed varying results. Incandescent white light and filter #153 showed significant increases in productivity. Filters #107, #110, #117, and #138 showed significant decreases in overall productivity. Filter #152 and #202 exhibited both significant increases and decreases in productivity while filter #110 did not produce any change in productivity (Table I).

Increased Productivity:

An evaluation of mean pounds per minute candled using incandescent white light indicates an overall increase in productivity with increasing intensity (Figure 1). Mean productivity for trimmer A at 500 and 1000 fc (experimental table) was not significantly different from the standard table. However, mean productivity increased from 1.6 lb./min., standard table, to 1.8 and 2.3 lb./min. at 2000 and 8000 fc, respectively. Productivity at 2000 fc and 8000 fc was also significantly greater than productivity at all other intensities evaluated on the experimental table. An increased of 17.6 and 15.8 percent at 2000 fc over productivity at 500 and at 1000 fc, respectively, was observed. A Comparison of productivity at 500, 1000 and 2000 to that at 8000 fc, indicates increases of 51.5, 49.3, and 28.9 percent in mean productivity.

Trimmer E using filter #153 showed a significant increase in productivity between 500 and 2000 fc, from 1.1 to 1.5 lbs./min. (Figure 2). Productivity between the standard table and 2000 fc; however, was not significantly different. This increase in productivity is probably the result of a decrease, but not significantly so, in productivity between the standard table and 500 fc.

An increase in productivity was also evident for trimmer EE using filter #152. Productivity increased from 0.5 lbs./min. on the standard table to 0.7 lbs./min. at 500 fc. and from 0.4 lbs./min. at 100 fc to 0.5 lbs./min. at 8000 fc (Figure 3). Productivity between the standard and higher light intensities (1000, 2000, and 8000 fc) were not significantly different. Decreases in productivity were evident between 500 fc and higher intensities on the experimental table. Although there were significant decreases in productivity, the percent decrease was less at higher intensities than at lower intensities. This worker also exhibited an increase in productivity between 1000 and 8000 fc on the experimental table.

There are no apparent reasons for the sporadic nature of the productivity values evident for this worker. Mental attitude may have been a contributing factor to this pattern. This worker was enthusiastic and interested in the experiment only during initial sessions. During subsequent sessions this worker was reluctant to participate, doing so only at the insistence of the worker's supervisor.

Trimmer C using filter #202 also showed an increase in productivity, from 2.4 to 2.8 lbs./min., between 1000 and 8000 fc on the experimental table; however, this increase is coupled with a significant decrease in productivity between the standard and 1000 fc (Figure 4). Productivity at 2000 and 8000 fc did not significantly increase from that at the standard table. When compared to the standard, productivity decreased from 2.8 to 2.4 lbs./min. at 1000 fc. The increase in productivity results from the decrease in productivity at 1000 fc and is not the result of an overall increase in productivity. This is evident by the fact that mean productivity on both the standard and experimental table at 8000 fc was 2.8 lbs./min.

Decreased Productivity:

Results for trimmer F using filter # 117 showed a significant decrease in productivity at 2000 and 8000 fc when compared to the standard table (Figure 5). Mean productivity decreased from 1.4 on the standard to 1.0 lbs./min. at 2000 fc and 1.2 lbs./min. at 8000 fc. Data for filter #138 (trimmer F) also indicate a significant decrease in productivity between the standard and 8000 fc and between 500 and 8000 fc (Figure 6). Mean productivity decreased from 1.4 lbs./min. on the standard to 1.3 and 0.9 lbs./min. at intensities of 500 and 8000 fc, respectively.

Results from trimmer GG using filter #107, at an intensity of 2000 fc showed a significant decrease in productivity when compared to both the standard and 1000 fc. (Figure 7). Mean productivity dropped from 0.6 to 0.4 lbs./min. at 2000 fc. Comparing results from intensities of 1000 and 2000 fc indicates a decrease in productivity from 0.8 to 0.4 lbs./min., a decrease of 44.9 percent. Productivity at other light intensities were not significantly different from that of the standard table.

The productivity of trimmer DD using filter #110 was not significantly effected (Figure 8). Mean productivity remained relatively constant at all light intensities.

Productivity vs. Time of Day:

Data from two trimmer were collected under conditions which provided a time series to evaluated the effect of wavelength and intensity on productivity trends during a work day. Insufficient continuous data were obtained from other trimmers to permit this type of an analysis. It should be noted that these data indicate possible trends only and insufficient data were available to conduct rigorous statistical analysis. However, these trends offer insight into how workers perform during a work day and should be considered before implementing any production changes. Future analysis of this aspect of worker productivity should be analyzed to determine long range effects of extended exposure to high light intensities.

Data for trimmer A using incandescent white light, encompasses a 5 hour period between 7 a.m. and 12 p.m. Productivity on the standard table and the experimental table at 500 and 1000 fc remains relatively constant throughout the work day (Figures 9-11). Although slight variations are evident, especially at the beginning and end of the work day, these can be attributed to smaller sample sizes during those time periods.

Productivity for trimmer A at 2000 and 8000 fc show considerably different trends. Initial productivity at 2000 fc was approximately the same as lower intensities but steadily increased over the next three hours (Figure 12). This increase was followed by a decline; however, the final productivity level appears to be higher than initial productivity. At 8000 fc productivity was initially higher than at lower intensities and also increased over the first two hours of work (Figure 13). This increase was also followed by a decline in productivity; however, in this case the decline was more drastic and extended. Final productivity at this intensity was lower than initial productivity.

Data for trimmer C using blue light showed productivity trends similar to trimmer A. This data encompasses an eight hour period from 8 a.m. to 5 p.m. with a one hour lunch break at 12 p.m. At both the standard and 1000 fc (no data was collected for 500 fc) productivity remained fairly constant throughout the day; however, a slight drop in productivity is evident after lunch (Figures 14-15). A slight difference is apparent in afternoon productivity. On the standard table productivity remained fairly constant at what appears to be a lower level than initial productivity. At 1000 fc afternoon productivity increases to a level at or above initial productivity.

Trimmer C productivity at 2000 and 8000 fc show different patterns than at lower intensities. At 2000 fc productivity steadily increased throughout the work day (Figure 16). There was no evidence of a decrease in productivity after the lunch break as at lower light intensities. Productivity at the end of the day was higher than initially. Productivity at 8000 fc was also higher at the end of the day than at the beginning; however, as with trimmer A, productivity tended to decrease after two hours exposure to this intensity (Figure 17). The rate of decrease at this wavelength appears to be less than with incandescent white light.

PARASITE DETECTION EFFICIENCY:

Detection efficiency was determined as the number of parasites removed/total number of parasites. Detection efficiency ranged from 0 to 100 percent in those fillets examined. Only one intensity-filter combination showed a significant change in detection efficiency. Trimmer E using filter #153 at 2000 fc showed a significant decrease (39%) in detection efficiency from the standard table (Figure 18). All other intensity-filter combinations tested did not significantly effect detection efficiency (Figures 19-25).

EVALUATION:

Personnel from the Fisheries Industrial Technology Center developed the methods, collected data, and performed data analysis. Cooperation between the Fisheries Industrial Technology Center and seafood processing plant managers and other personnel was crucial to the success of the project. Line workers who regularly trimmed codfish fillets were observed at All Alaska Seafoods, Cook Inlet Processors, and East Point Seafoods, Kodiak, Alaska to generate detection efficiency and productivity data. Some observations were also collected at King Crab Incorporated, but were incomplete data sets and, consequently, not included in the data analysis.

The overall goal of this project was to develop a vision system that would detect bones and parasites, and could be used to automate fillet inspection. To accomplish this, the initial objective was to determine the wavelength and intensity of candling light which produced the greatest detection efficiency. Results of this study was intended to provide fish processors with information that could optimize product quality and detection efficiency, and increase the value of Alaskan whitefish species as well as strengthen the foundation of the industry.

The project produced information on wavelengths and light intensities that may increase processing line performance in whitefish processing plants. Although the data was gathered by observing detection of parasites, the results may be used for detection and removal of other defects such as blood spots. The utilization of the information may increase worker productivity which will benefit the economics of the processors. Processing costs per pound of product will be reduced while defect removal is enhanced.

The data obtained on parasite detection efficiency can not be used to benefit the industry. In this study, no differences were apparent in efficiency when workers were subjected to varying wavelengths and light intensities.

Results of this study will be presented to any interested public and seafood industry representative. Hopefully, seafood processing plant productivity will increase and costs of quality control due to parasite detection will be reduced. Consequently, the whitefish industry may become more competitive in the world market.

The benefits of the results will be long-lasting. Although a few methods have been investigated for removal of parasites from fish muscle, the candling technique has been the only technique used to detect parasites. At present, no new methods have been developed to optimize detection of parasites. The results of this project may initiate further investigations into the effects of candling light on worker productivity to determine maximum effective light levels.

The need for federal assistance is appropriate because information obtained from the study will benefit both the private seafood processors as well as publicly owned fisheries. It would be difficult for the private sector to absorb all costs of research. Private industry (processing plants) incurred costs for the project by contributing employee time for observations with some loss of labor, fillets for sampling, and other operations equipment to run the experiment (i.e., electric scales, baskets, bags, tables, extension cords, space).

Trimming procedures were not completely consistent throughout processing plants, because of different working conditions. In one location there was not a constantly running water source. Workers were required to occasionally retrieved a to wet down the fillets or the trimming surface. At all other locations, each worker had a hose directly above the work place which had water constantly running over the working surface and fillets.

Background variables between different plants and different days affect worker productivity. The effects of external factors that require further investigation are plant operations, fish variability, background environmental factors, and psychological factors. Processing plants vary with background light intensity, electricity failures (light and cutter power), water availability, personnel/supervisory changes, fillet technique changes, inconsistent starting times. Fish variability include fillet thickness, fillet infestation, fillet freshness and fillet size. Environmental factors to consider are machinery noise, odors, front-loader traffic noise and exhaust, and music. Psychological factors are worker fatigue, worker conscientiousness, different daily moods, and boredom.

CONCLUSIONS:

Results indicate worker productivity is directly related to an increase in intensity of incandescent white light. An increase in productivity at higher intensities (2000 foot-candles and above) is evident with 50% of the test conditions. Production levels of trimmer A, for example, increased by 13.6 and 32.8 percent by increasing light intensity to 2000 fc and 8000 fc, respectively. This increased productivity occurred regardless of the fact that trimmers were required to move individual fillets more frequently on the experimental table during the candling process. This was the result of the smaller lighted surface used on the experimental table.

An analysis of hourly productivity; however, indicates that productivity at 8000 fc may not be sustainable. Over a four hour work period, trimmer A productivity initially increased but by the end of the work period had decreased to a level below initial productivity. Similar results for trimmer C over an eight hour period suggest that eye fatigue or some other factor may limit the effectiveness of candling at high light intensities. Hourly productivity at 2000 fc; however, does not show as extreme a cyclic pattern. At this intensity, productivity increased over each four hour period; resulting in a higher productivity at the end of the work day than at the beginning.

The reasons for increased productivity at higher light intensities appears to be the ability of the trimmer to detect the parasite more rapidly than at lower intensities. Specific reasons for this were not apparent from this study. Detection and recognition of an object is a complex phenomena which encompasses physical, psychological, and physiological aspects. Stimuli to the visual system relative to any particular object is highly variable. Research has shown that movements of the eye, head, or object changes the retinal image through displacement, dilation, contraction, or rotation. With parasites embedded in a fillet, the retinal image will also change as parts disappear or emerge. In addition, the edges of the object image become blurred and many of its finer details are lost. The overall effect is that parts of the parasite parts may be occluded, and edges may not be physically distinguishable from the edges and surface detail of surrounding fillet due to surface markings, shadows, and reflections.

The level of illumination has been shown to be critical in object detection and recognition. The visual process depends upon differences in light energy. This differential, contrast threshold, is the ratio of the luminance difference between an object and its surroundings. As the luminance of the background field is reduced, it becomes progressively more difficult to see an object. At high field luminance the reduction in visual performance is less rapid (Overington 1976). There is also evidence that negative contrasts (background brighter than the object of interest) are more easily detectable than equivalent positive contrasts (Patel and Jones 1968; Cohn 1974).

Study results indicate no improvement in detection efficiency using optical detection techniques. These results and those of similar research (Power 1958, Valdimarsson et al 1985) have convinced us that optical techniques have limited potential for improving parasite detection efficiency.

The problem with the candling technique is that scattering of light passing through the fillet make it impossible to see parasites deeper than a few mm in the flesh. Shadows from buried parasite are masked by the scattered light from flesh above the parasite making it difficult to see. Muscle fibers may also act as optic fibers which conduct light around the parasite.

LITERATURE CITED

Agersborg, H.P.K. 1918. Nematodes in marketable fishes. *Science* 48: 493-495.

Arthur, J.R. 1984. A survey of the parasites of walleye pollock (*Theragra chalcogramma*) from the northeastern Pacific Ocean off Canada and a zoogeographic analysis of the parasite fauna of the fish throughout its range. *Canadian J. Zoo.* 62: 675-684.

Arthur, J.R., L. Margolis, D.J. Whitaker, and T.E. McDonald. 1983. A quantitative study of economically important parasites of walleye pollock (*Theragra chalcogramma*) from British Columbian waters and effects of postmortem handling on their abundance in the musculature. *Canadian J. Fish. Aquat. Sci.* 39(5): 710-726.

Cheng, T.C. 1973. Human parasites transmissible for seafood and related problems. In C.O. Chichester and H.D. Grahm (eds.) *Microbial Safety of Fishery Products.* Academic Press, London.

Chitwood, M.B. 1970. Nematodes of medical significance found in market fish. *Amer. J. Tropical Med. Hygiene.* 19: 599-602.

Cohn, T.E. 1974. A new hypothesis to explain why the increment threshold exceeds the decrement threshold. *Vision Research* 14: 1277-1283.

Hughes, S.E. and N.B. Parks. 1975. Alaskan groundfish - results of recent trawl surveys and joint industry - NMFS production fishing trials. National Fisherman 55(13): 34-40.

Jackson, G.J. , J.W. Bier, W.L. Payne, T.A. Gerding, and W.G. Knollenberg. 1978. Nematodes in fresh market fish of washington, D.C. area. *Journal of Food Protection* 41(8): 613-620.

Margolis, L. 1977. Public health aspects of "codworm" infection: a review. *J. Fish. Res. Bd. Canada* 34: 886-898.

Morris, B.F., M.S. Alton, and H.W. Braham. 1983. Living marine resources of the Gulf of Alaska. NOAA Technical Memorandum NMFS F/AK-5.

Meyers, B.J. 1976. Research then and now on the anisakidae nematodes. *Trans. Amer. Microscopial Soc.* 95: 137-142.

Olson, R.E. 1986. Marine fish parasites of public health importance. In D.F. Kramer and J. Liston (eds.) *Seafood quality Determination*. Elsevier, Amsterdam.

Olson, R.E. and D. Landkamer. 1985. Parasites of commercially important marine fishes collected in the vicinity of Kodiak Island, Alaska October 1984. Research Report to University of Alaska, Fishery Industrial Technology Center, October 1985, 53 p.

Overington, I. 1976. *Vision and Acquisition*. Crane, Russak & Co. Inc., New York. 380 pp.

Patel, A.S. and R.W. Jones. 1968. Increment and decrement visual thresholds. *J. Opt. Soc. Am.* 58:696-715.

Valdimarsson, G. H. Einarsson and F.J. King. 1985. Determination of parasites in fish muscle by candling technique. *J. Assoc. Off. Anal. Chem.* 68(3):549-551.

Table I. Light/color combinations exhibiting significant differences in mean worker productivity.

Trimmer	Filter#	Intensity Range	Lb/min Change	Percent Change
A	None	std-2000	+0.217	+13.8
		std-8000	+0.732	+46.8
		500-2000	+0.266	+17.6
		500-8000	+0.781	+51.6
		1000-2000	+0.243	+15.8
		1000-8000	+0.758	+49.3
		2000-8000	+0.515	+29.9
EE	152	std-500	+0.223	+46.3
		500-1000	-0.338	-47.9
		500-2000	-0.243	-34.3
		500-8000	-0.152	-21.6
		1000-8000	+0.186	+50.7
E	153	500-2000	+0.401	+35.1
C	202	std-1000	-0.408	-14.2
		1000-8000	+0.342	+14.1
F	138	std-8000	-0.538	-37.5
		500-8000	-0.403	-30.9
F	117	std-2000	-0.402	-27.9
		std-8000	-0.277	-19.3
GG	107	std-2000	-0.172	-29.2
		1000-2000	-0.340	-44.9
DD	110	None		

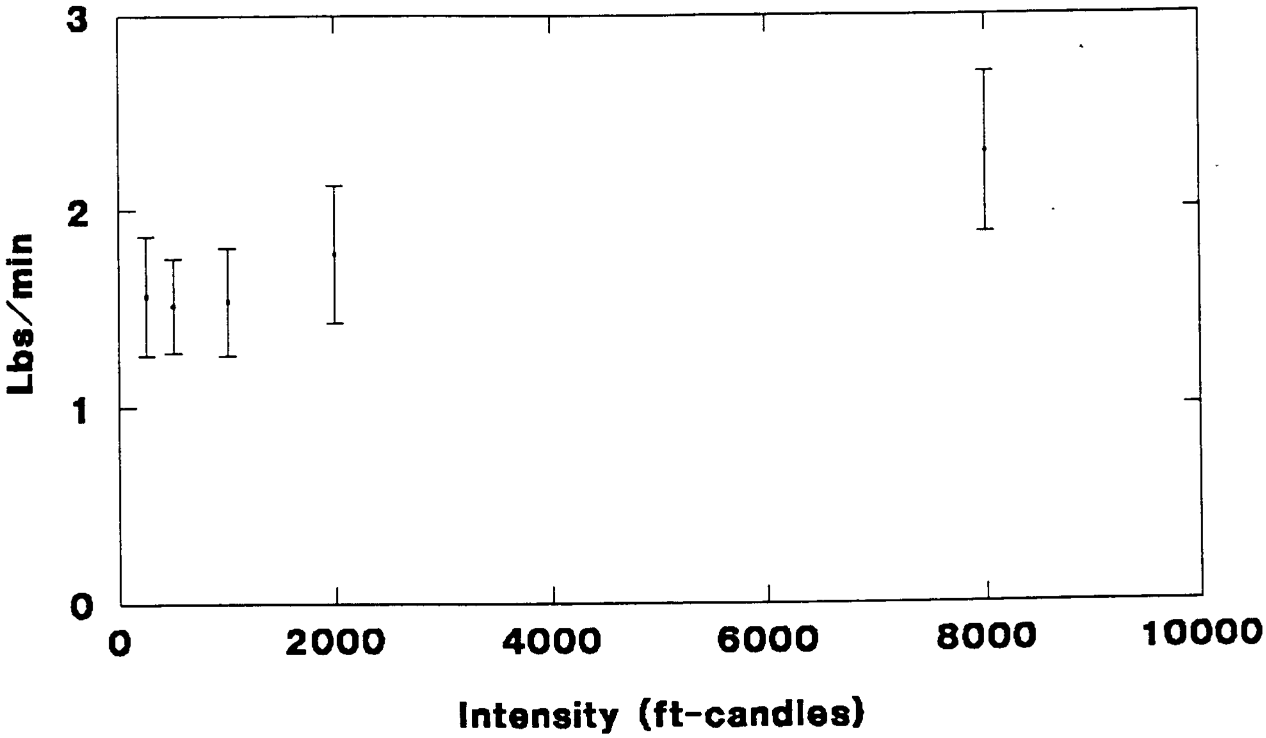

Figure 1. Effect of light intensity on worker productivity using incandescent white light.

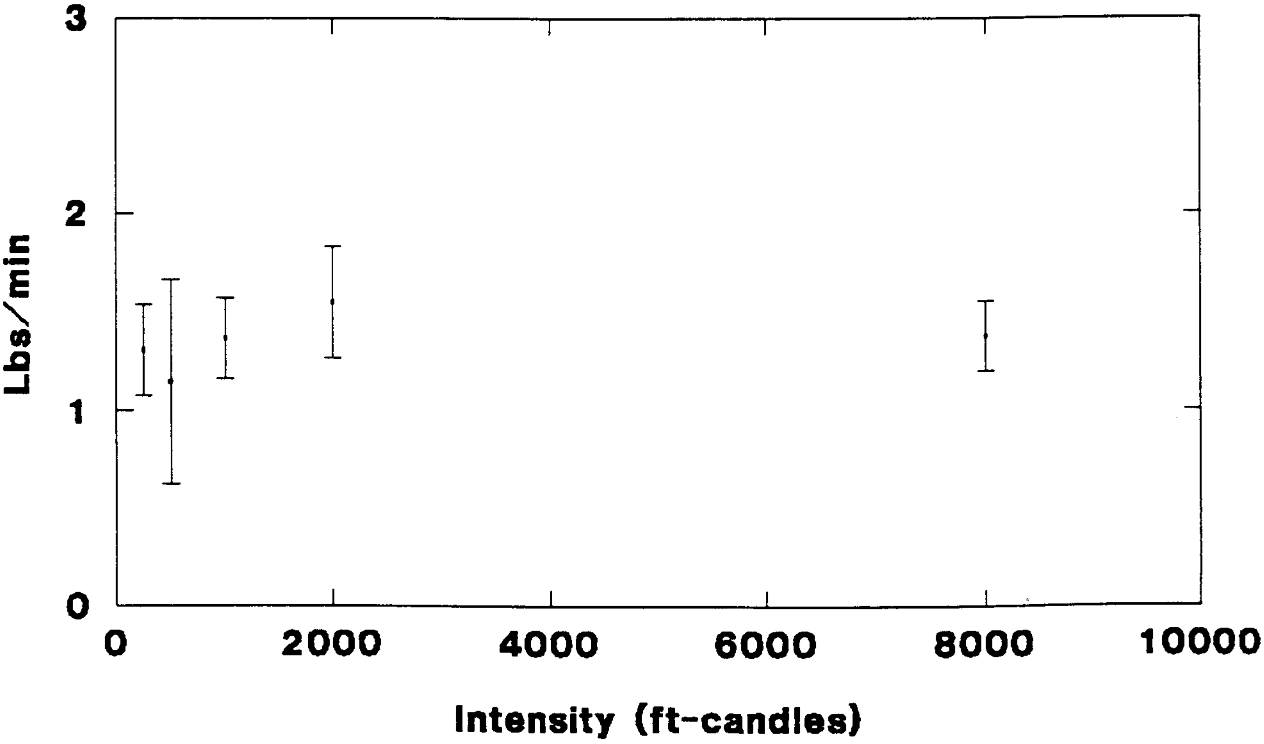

Figure 2. Effect of light intensity on worker productivity using filter #153, pale salmon.

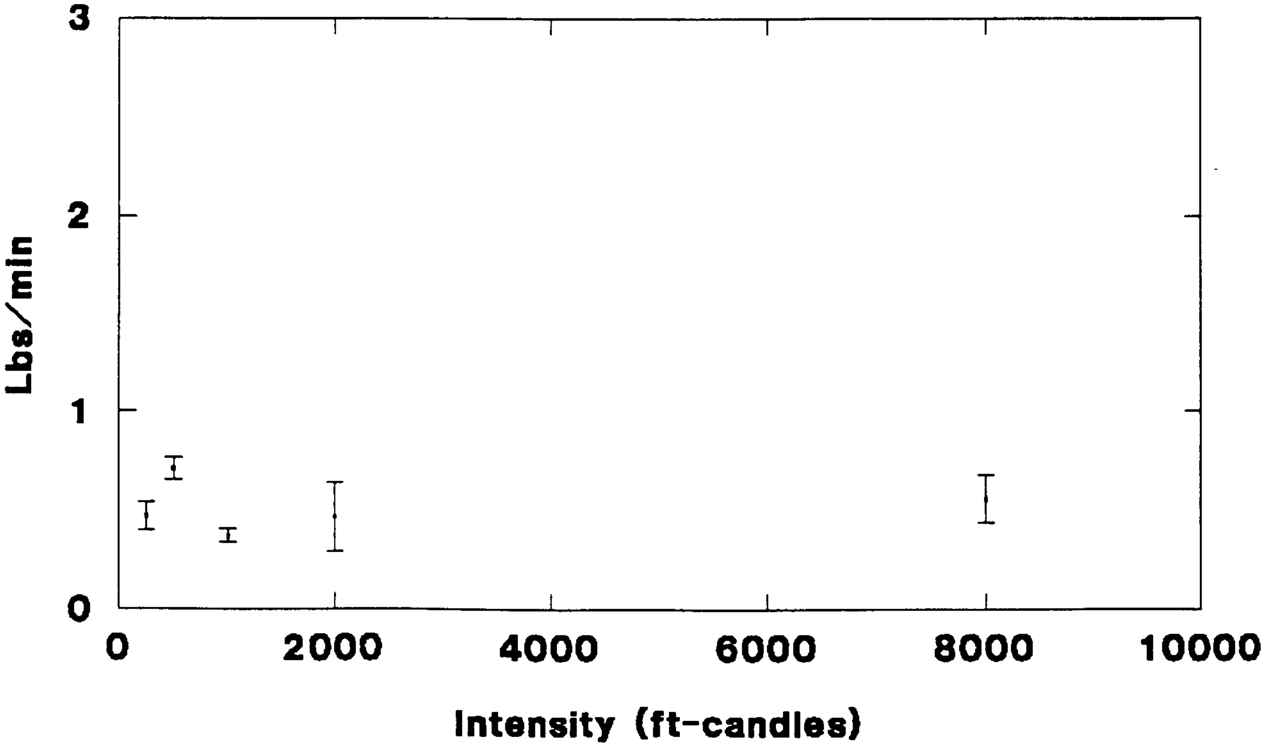

Figure 3. Effect of light intensity on worker productivity using filter #152, pale gold.

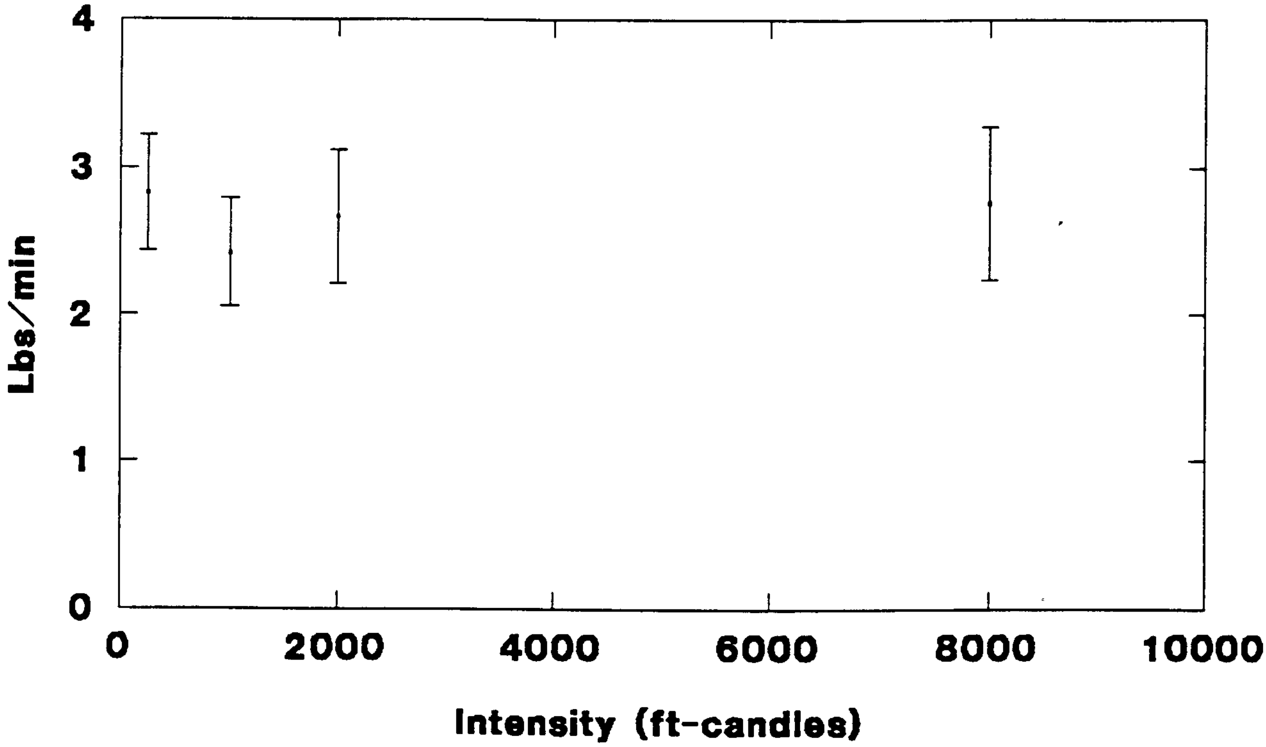

Figure 4. Effect of light intensity on worker productivity using filter #202, blue.

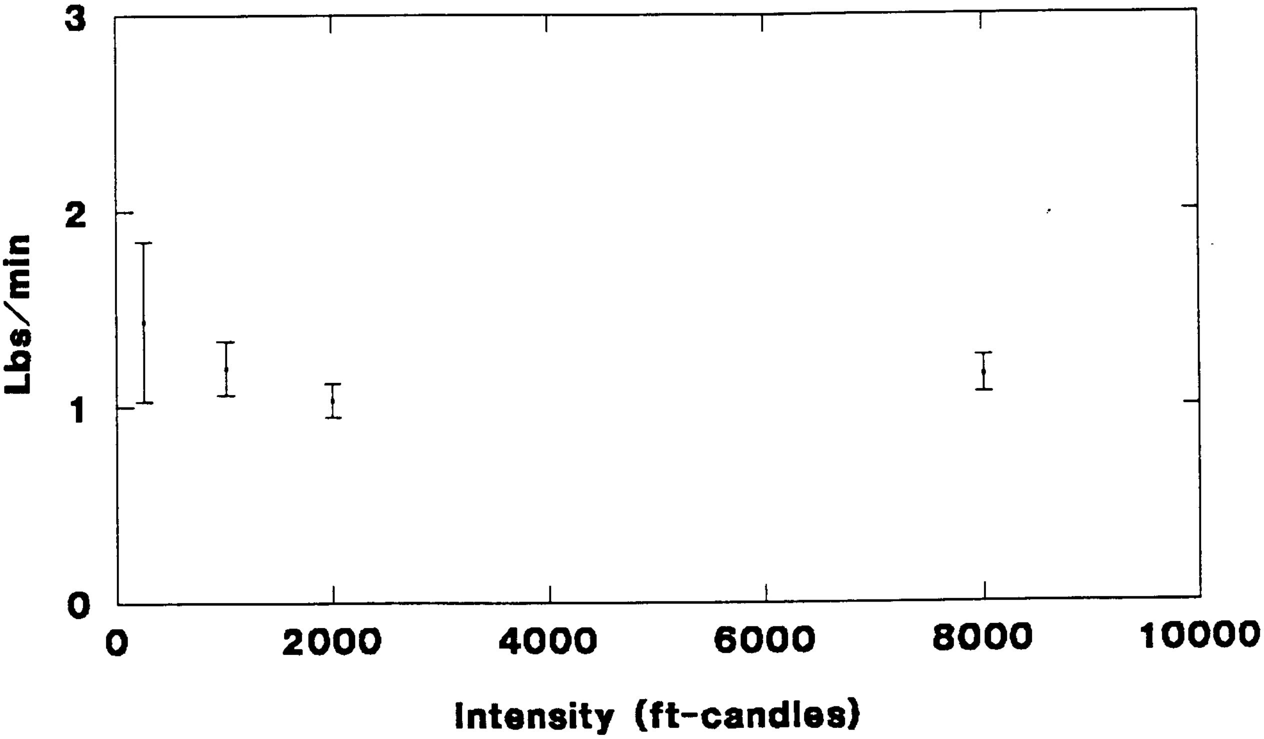

Figure 5. Effect of light intensity on worker productivity using filter #117, steel blue.

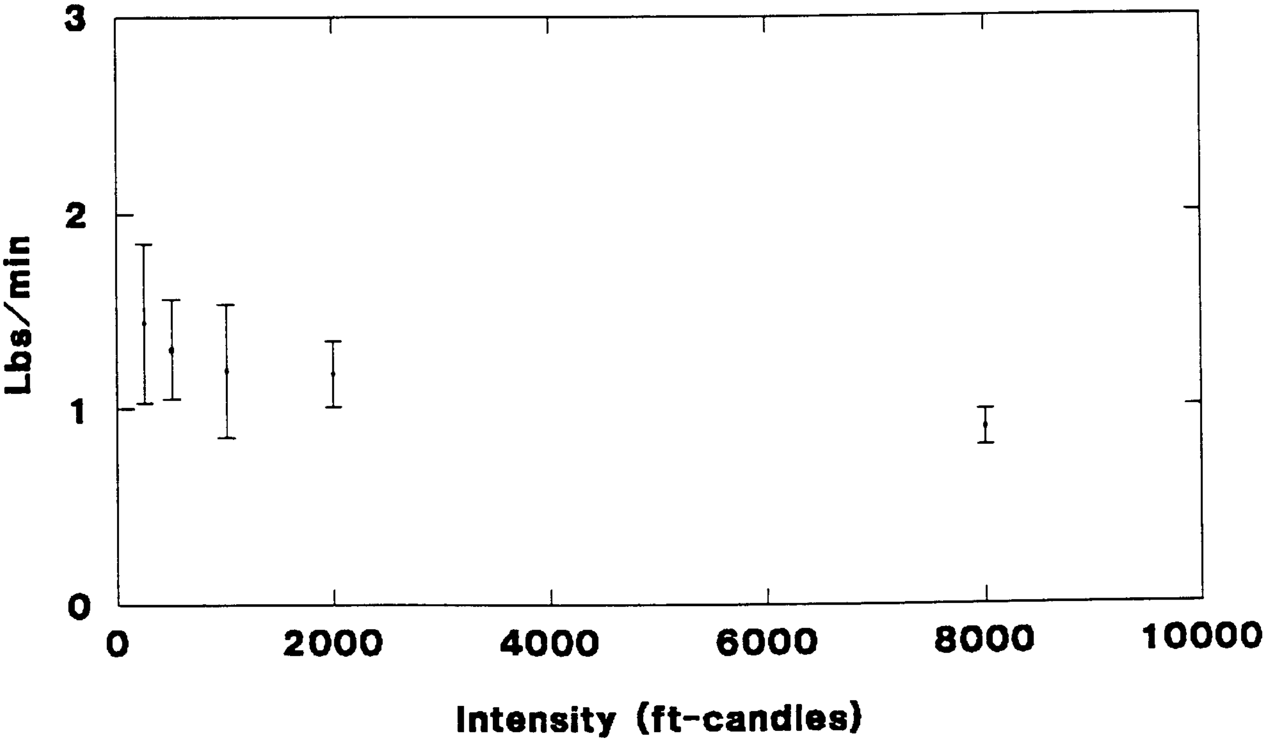

Figure 6. Effect of light intensity on worker productivity using filter #183, pale green.

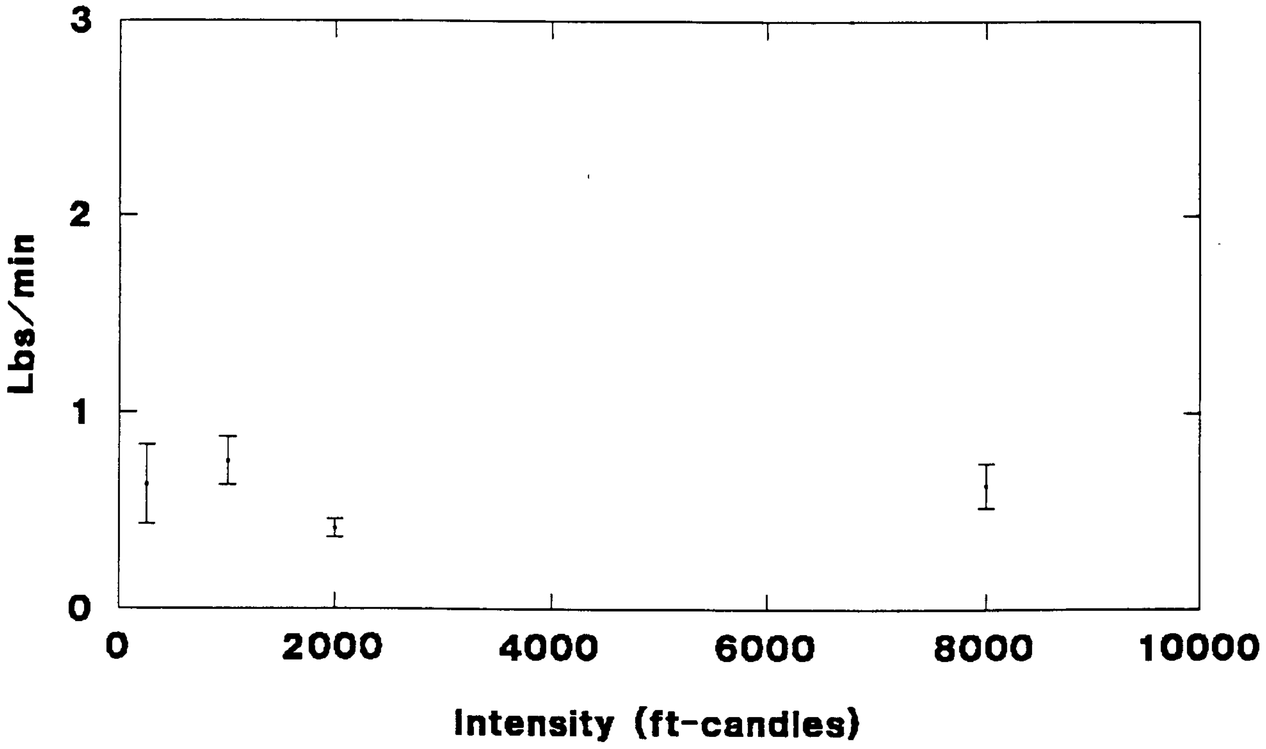

Figure 7. Effect of light intensity on worker productivity using filter #107, light rose.

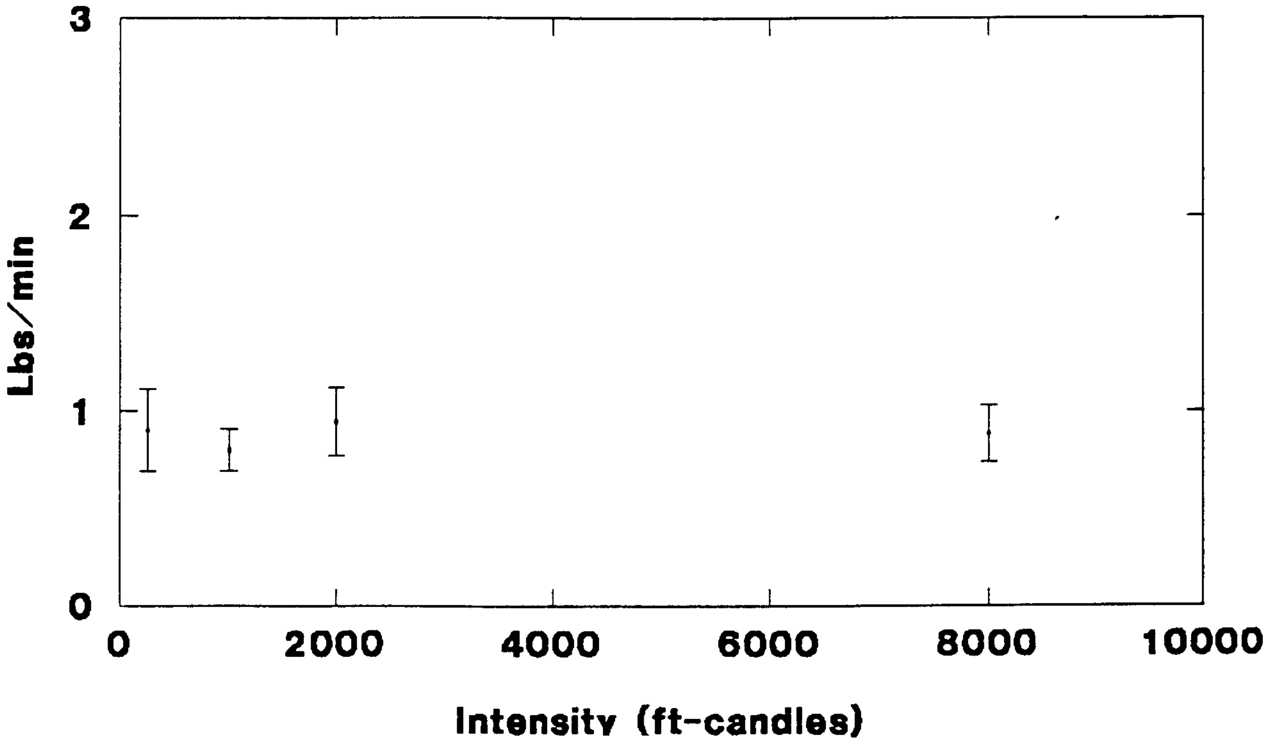

Figure 8. Effect of light intensity on worker productivity using filter #110, middle rose.

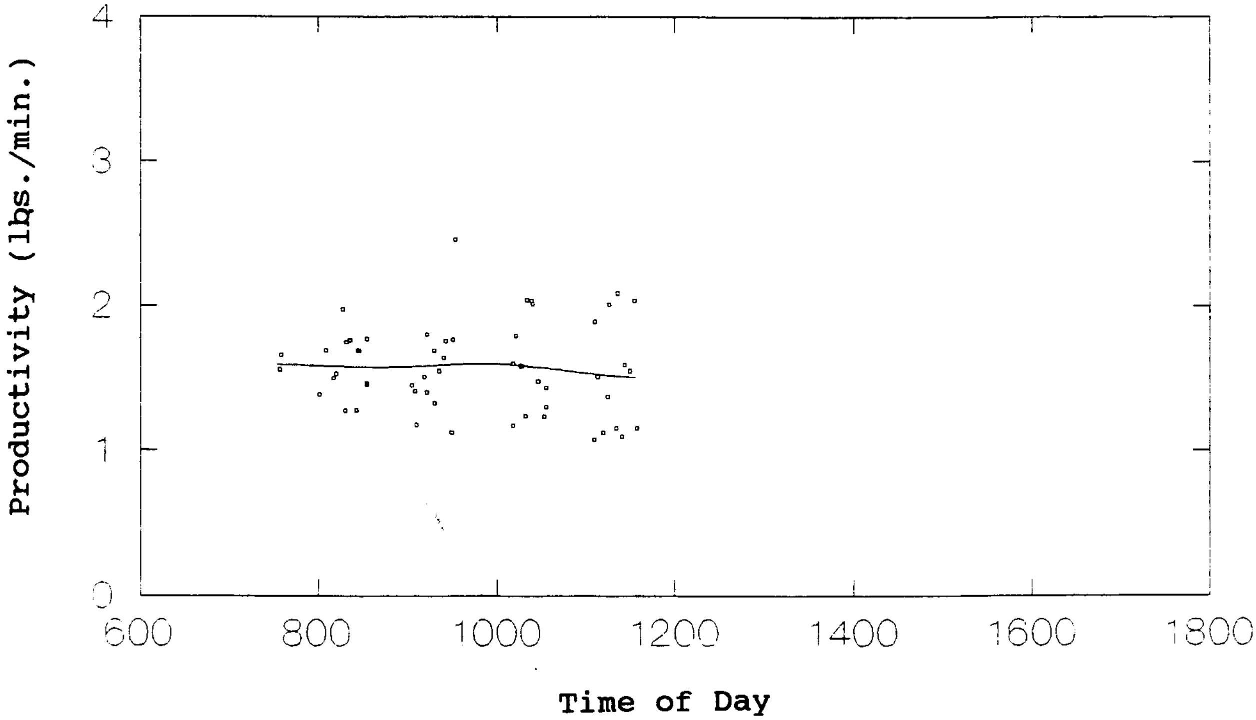

Figure 9. Variation in Trimmer A productivity over time, standard table

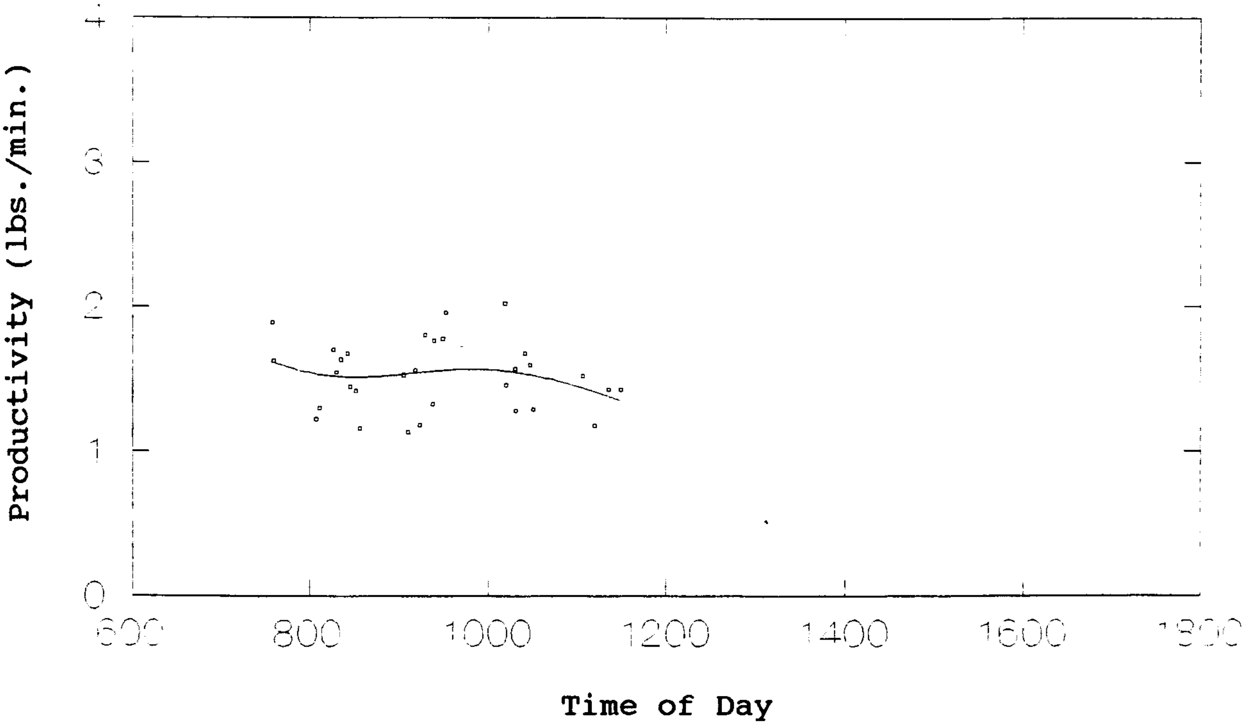

Figure 10. Variation in Trimmer A productivity over time, 500 fc.

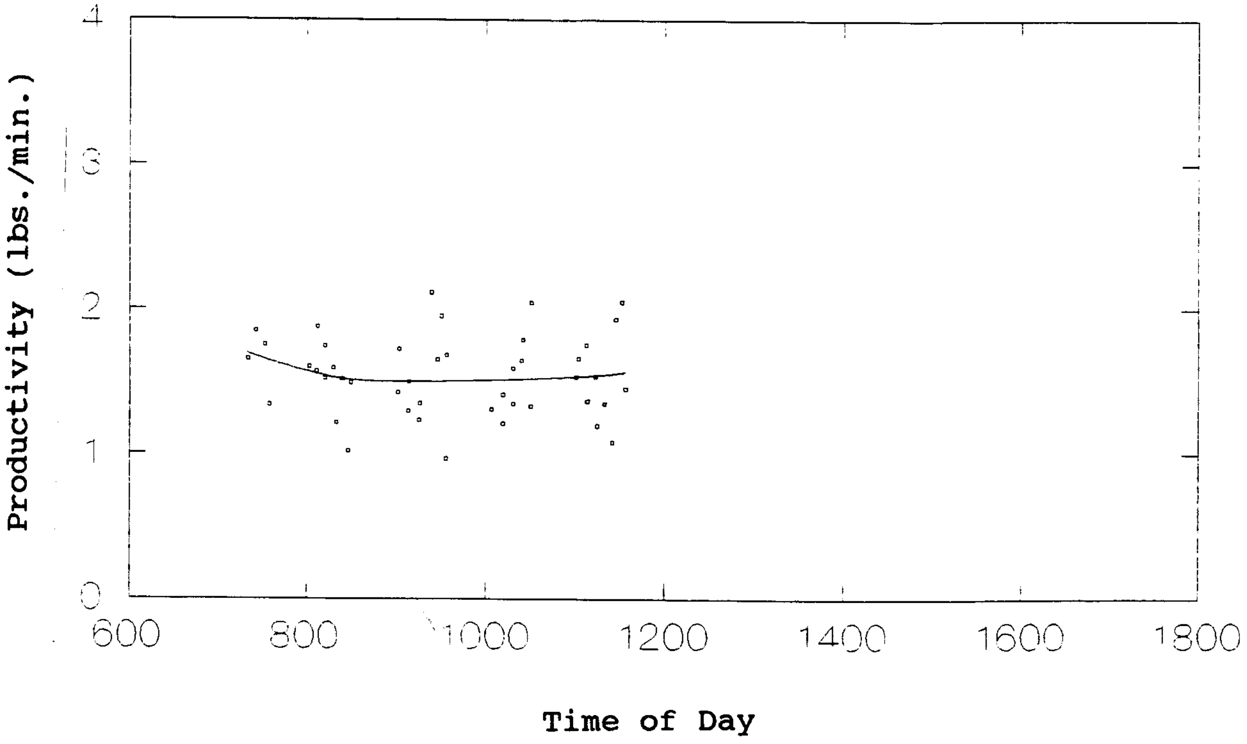

Figure 11. Variation in Trimmer A productivity over time, 1000 fc.

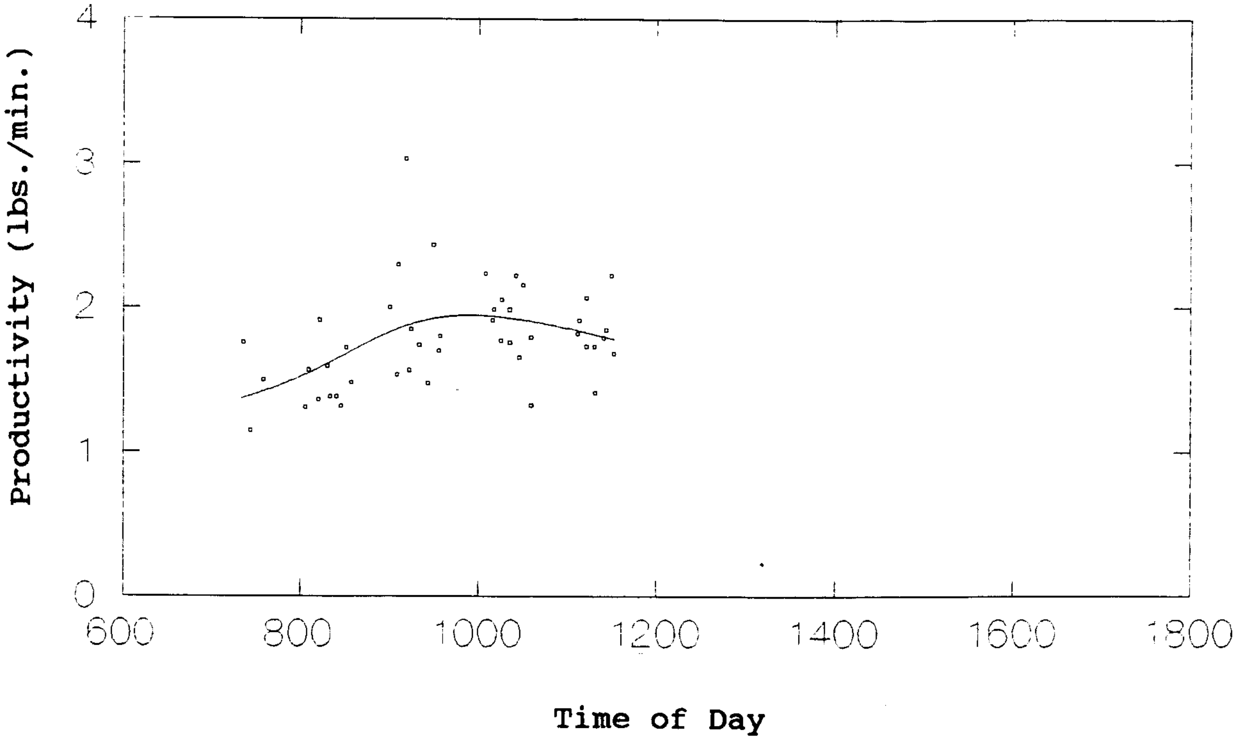

Figure 12. Variation in Trimmer A productivity over time, 2000 fc.

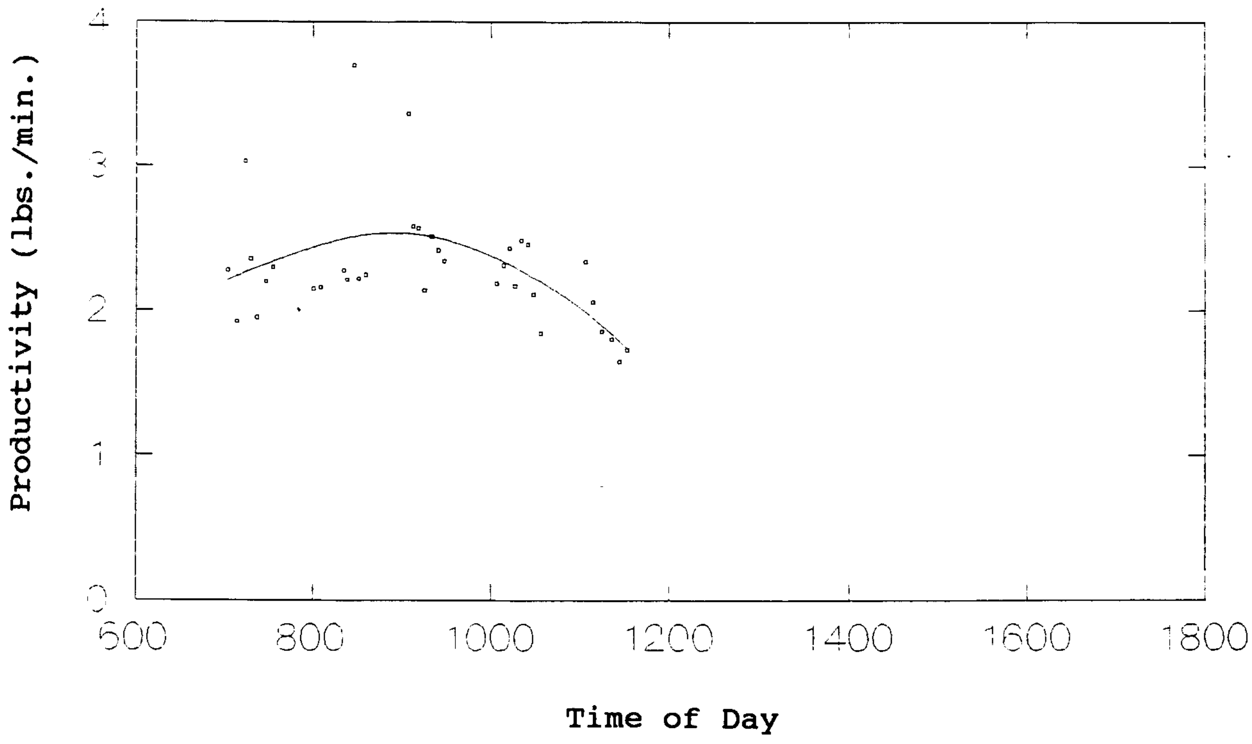

Figure 13. Variation in Trimmer A productivity over time, 8000 fc.

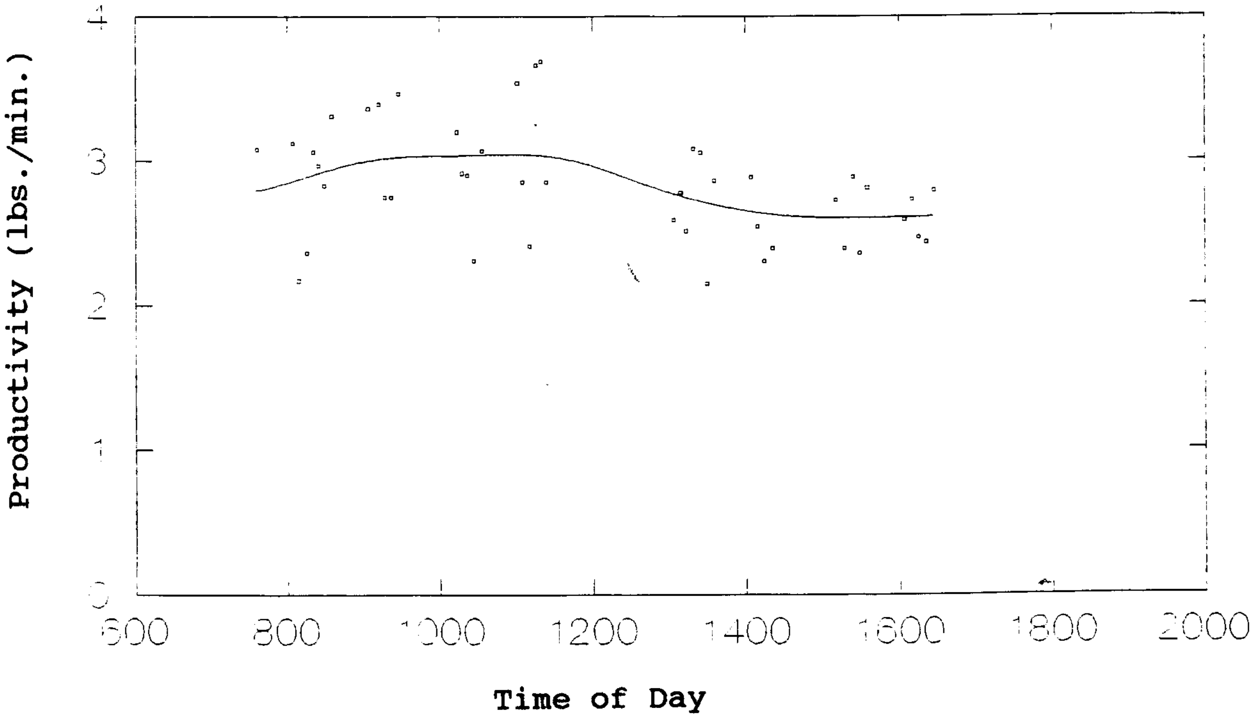

Figure 14. Variation in Trimmer C productivity over time, standard table

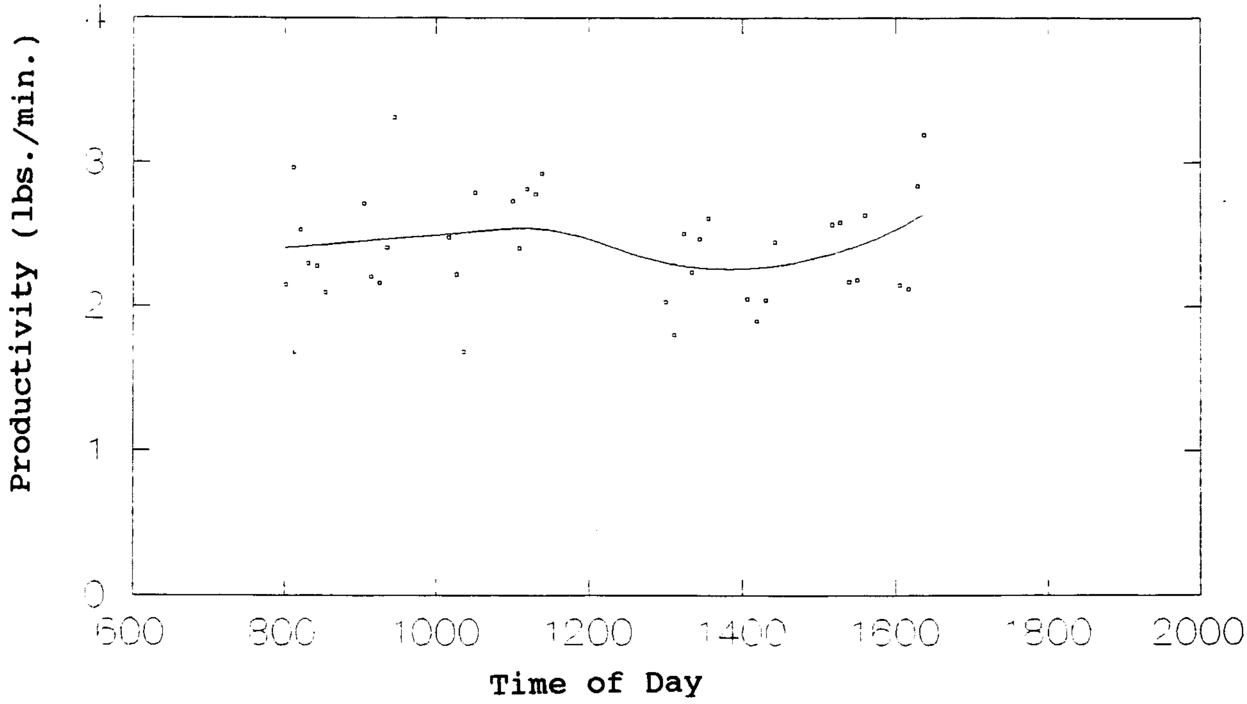

Figure 15. Variation in Trimmer C productivity over time, 1000 fc.

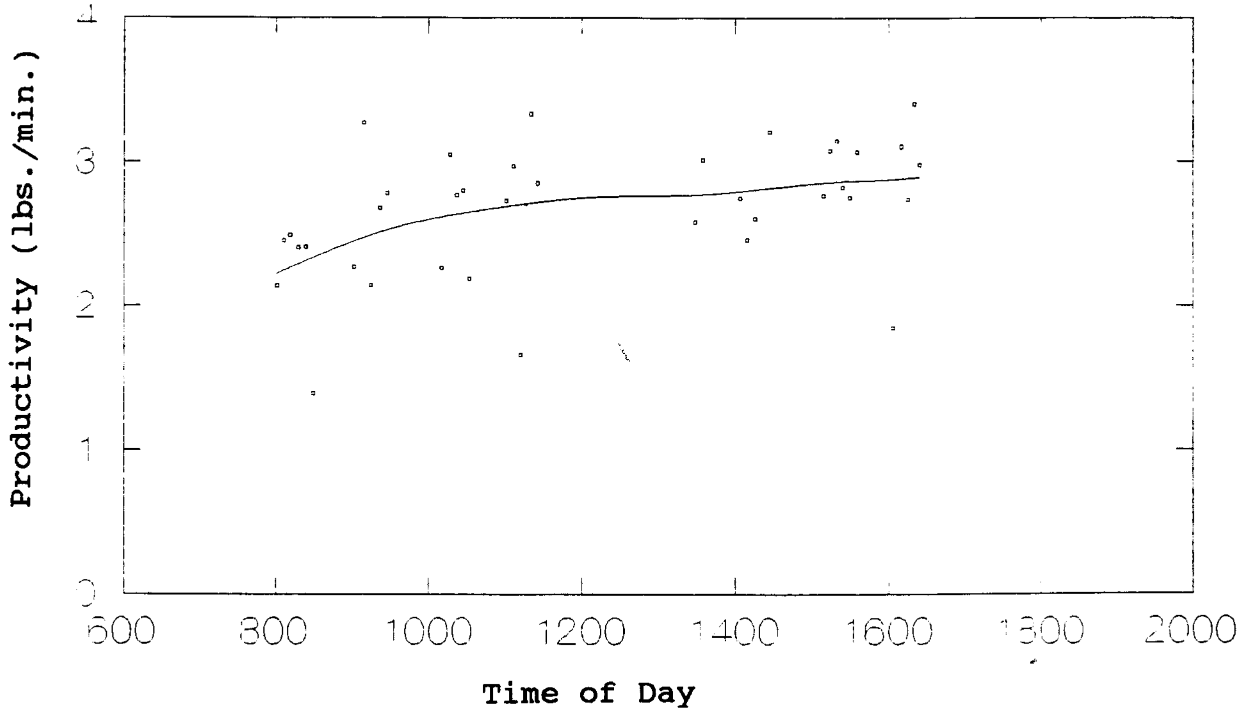

Figure 16. Variation in Trimmer C productivity over time, 2000 fc.

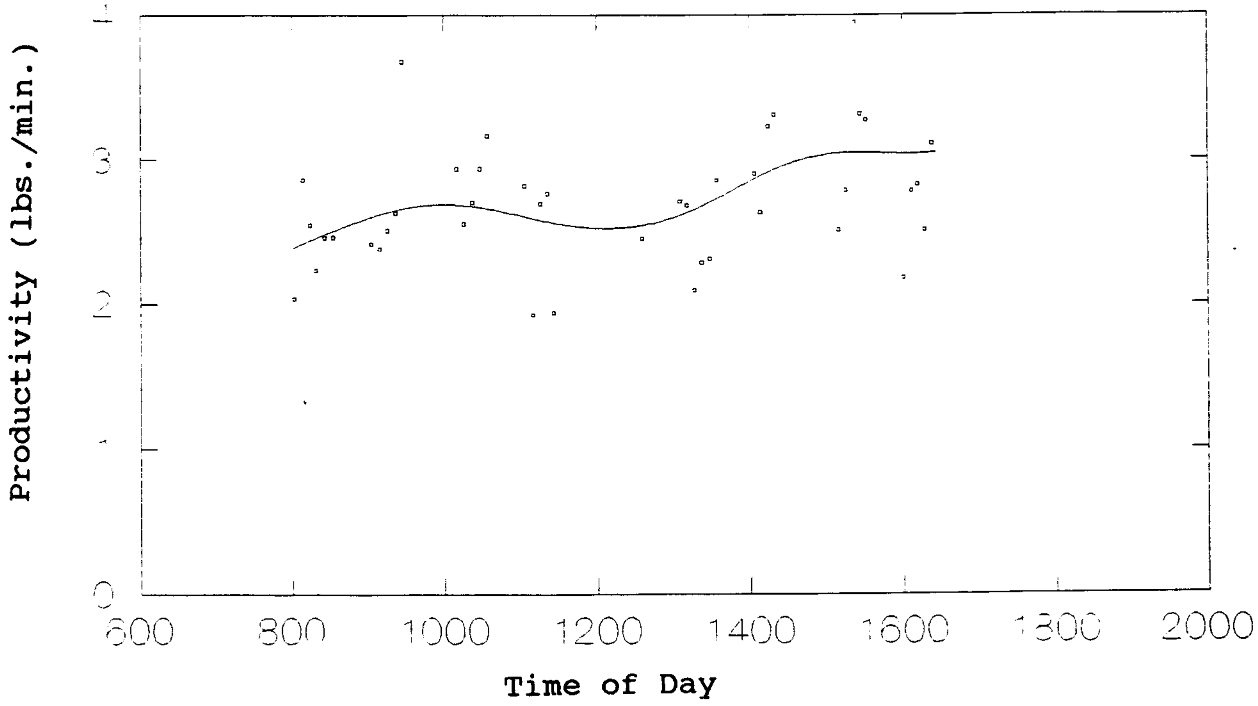

Figure 17. Variation in Trimmer C productivity over time, 8000 fc.

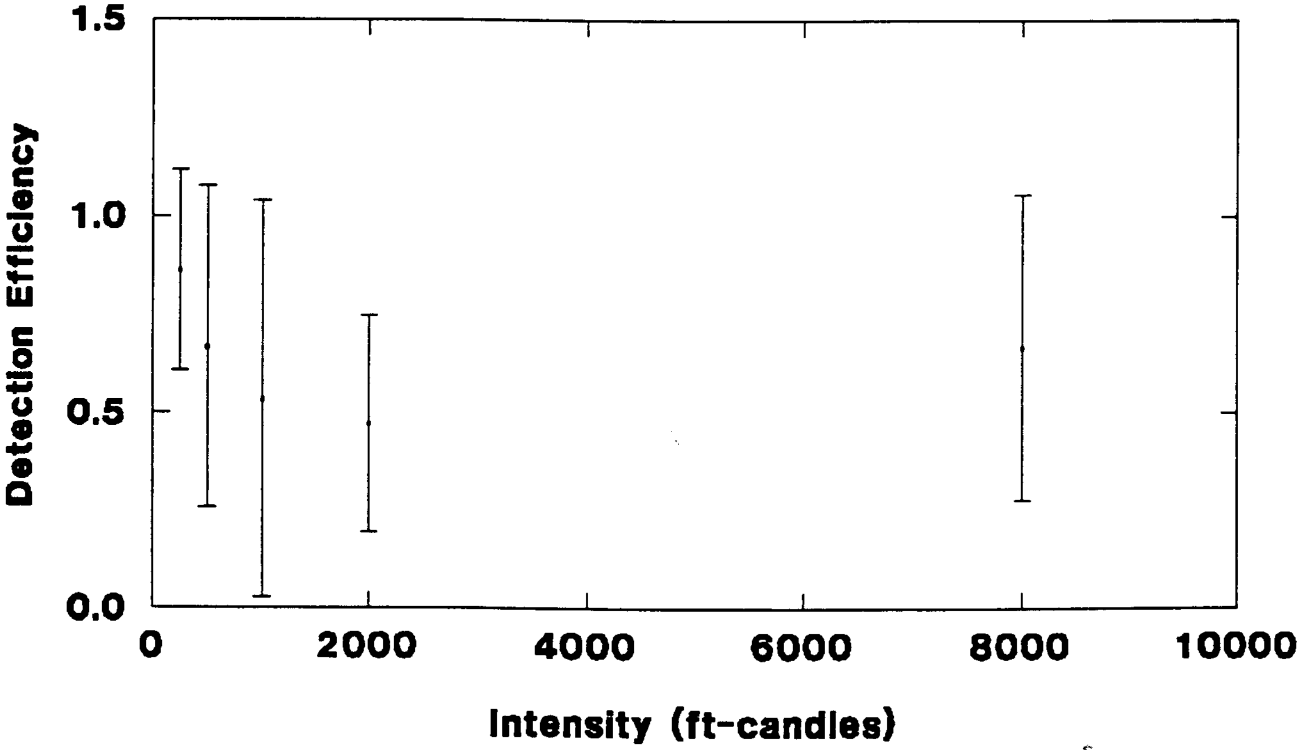

Figure 18. Effect of light intensity on detection efficiency using filter #153, pale salmon.

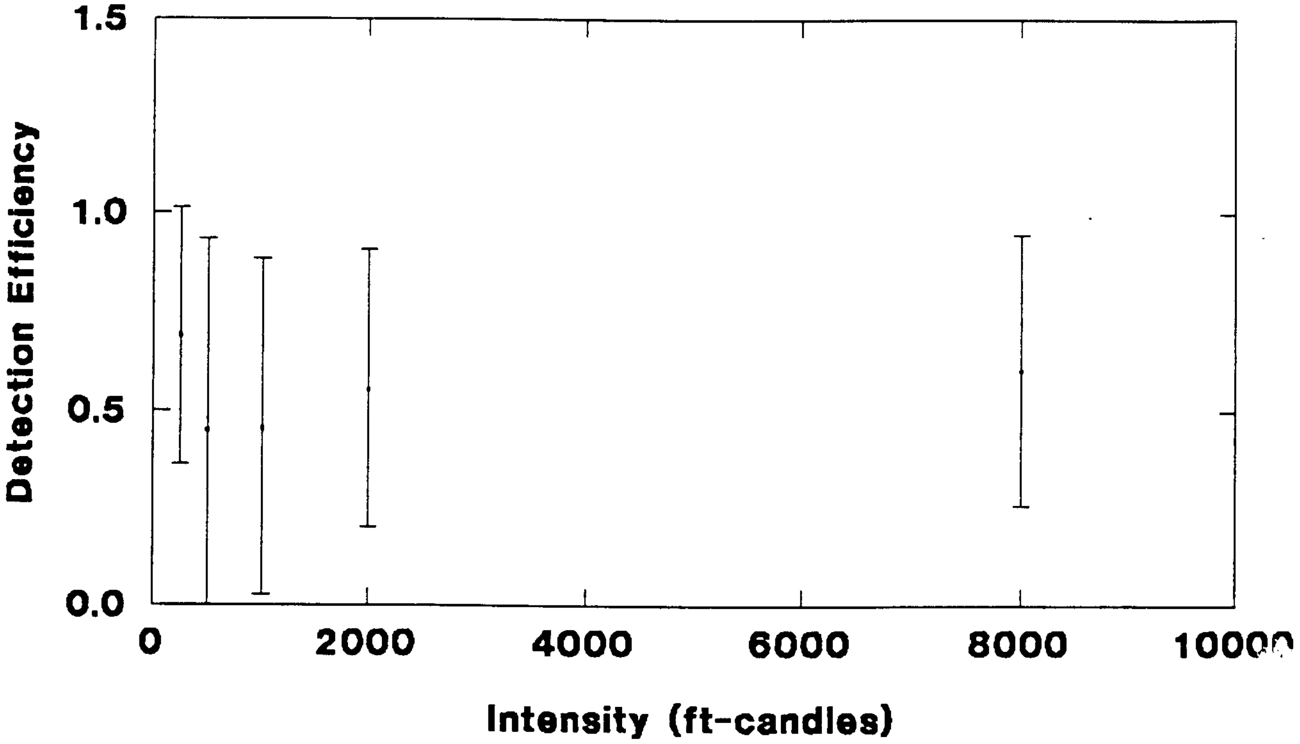

Figure 19. Effect of light intensity on detection efficiency using incandescent white light.

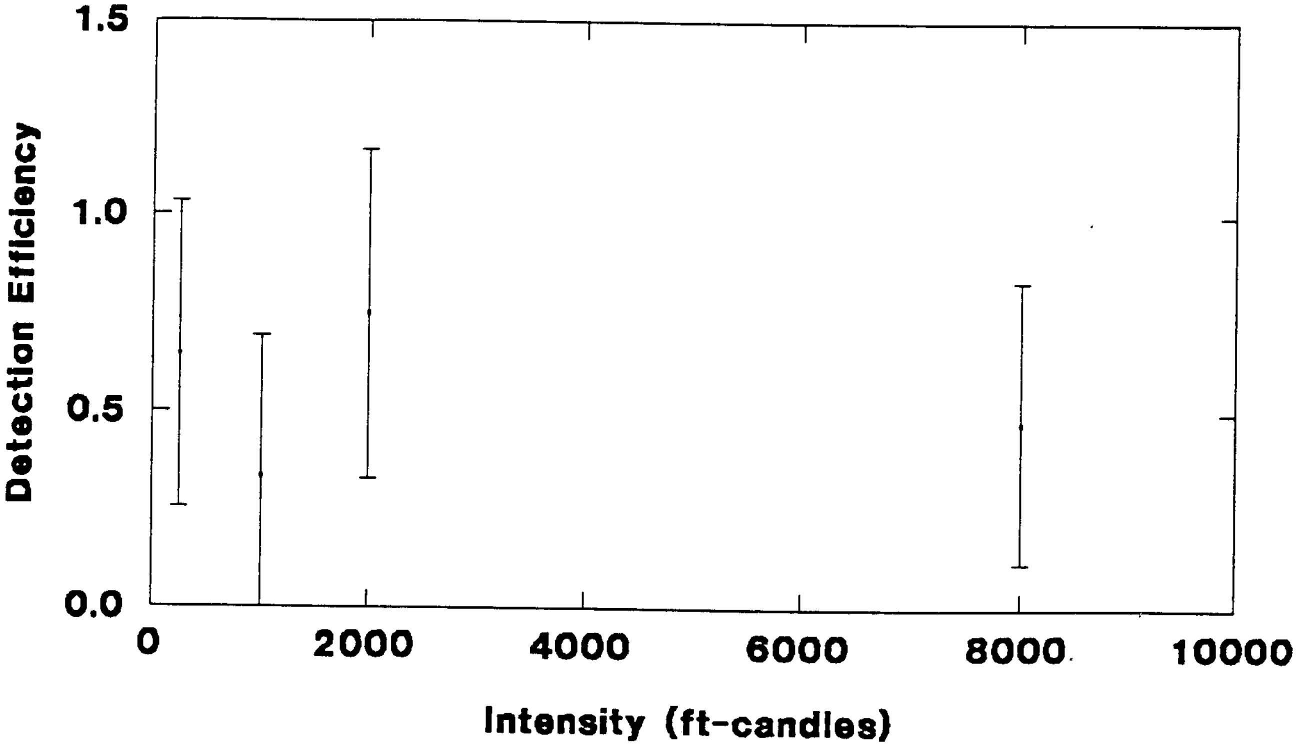

Figure 20. Effect of light intensity on detection efficiency using filter #152, pale gold.

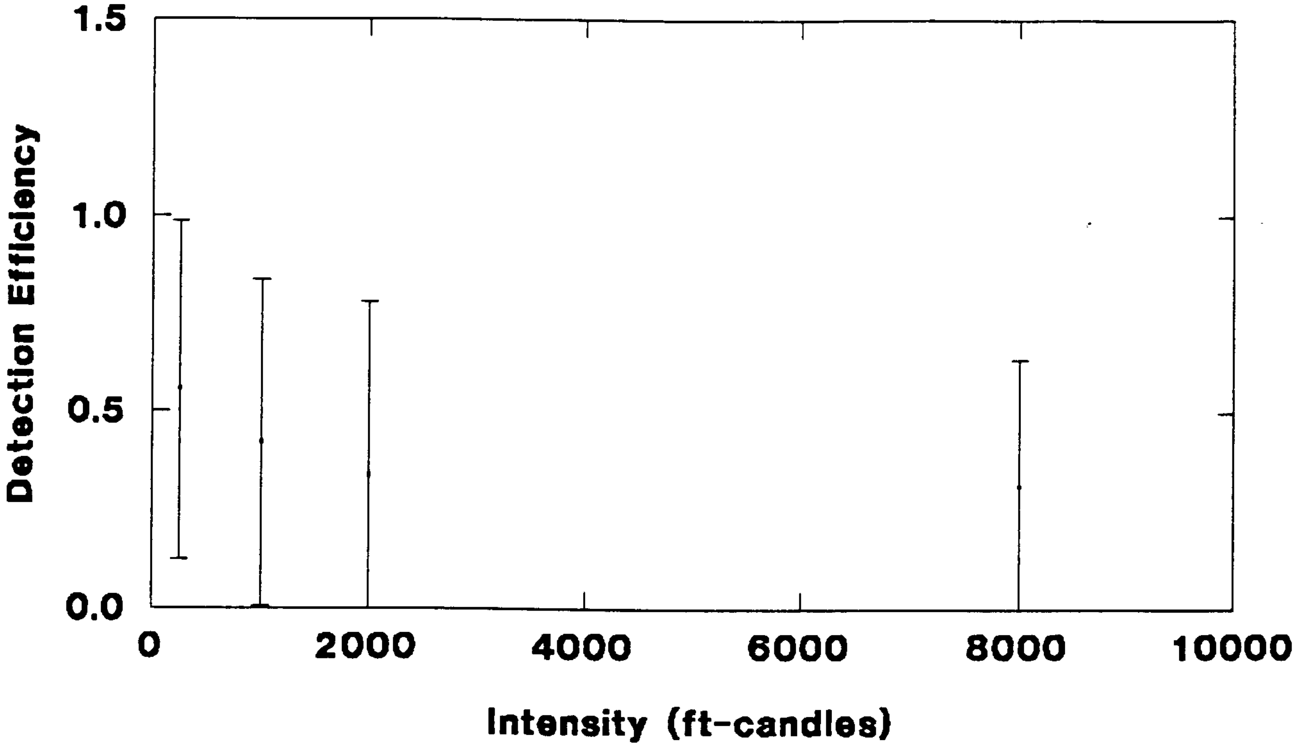

Figure 21. Effect of light intensity on detection efficiency using filter #202, blue.

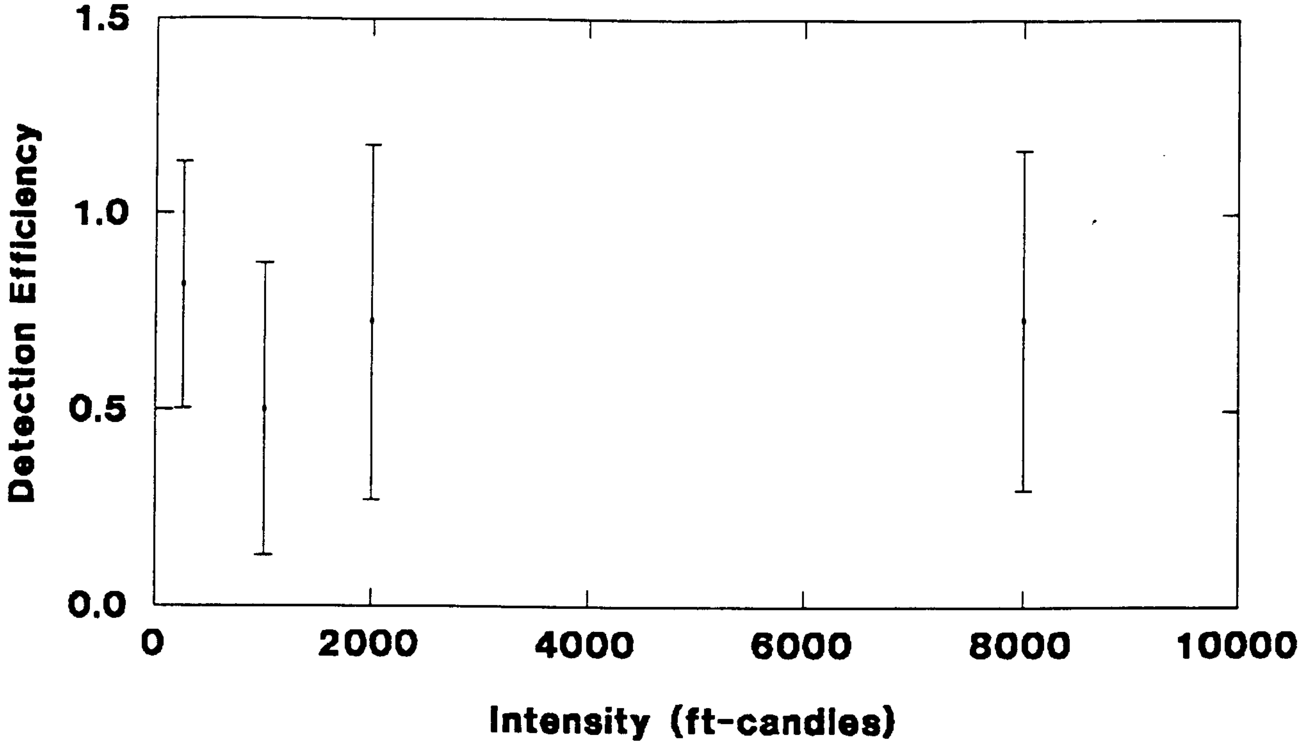

Figure 22. Effect of light intensity on detection efficiency using filter #117, steel blue.

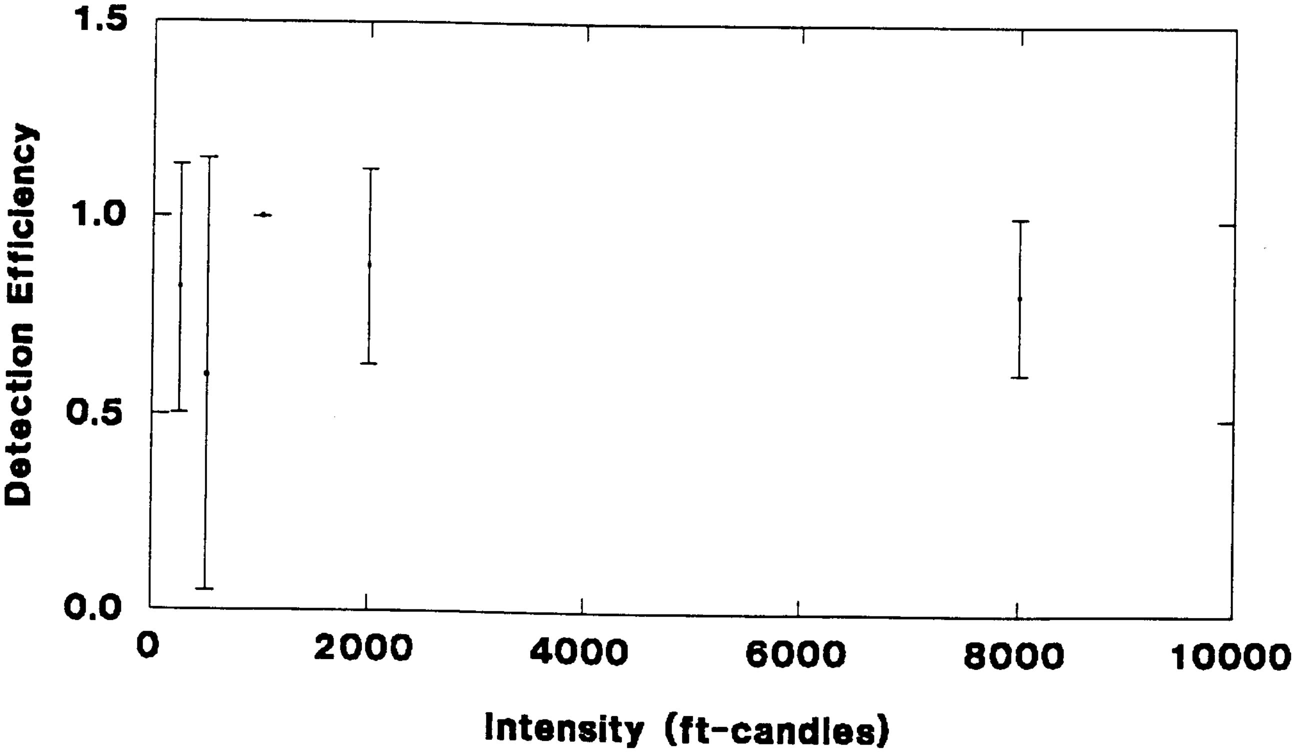

Figure 23. Effect of light intensity on detection efficiency using filter #183, pale green.

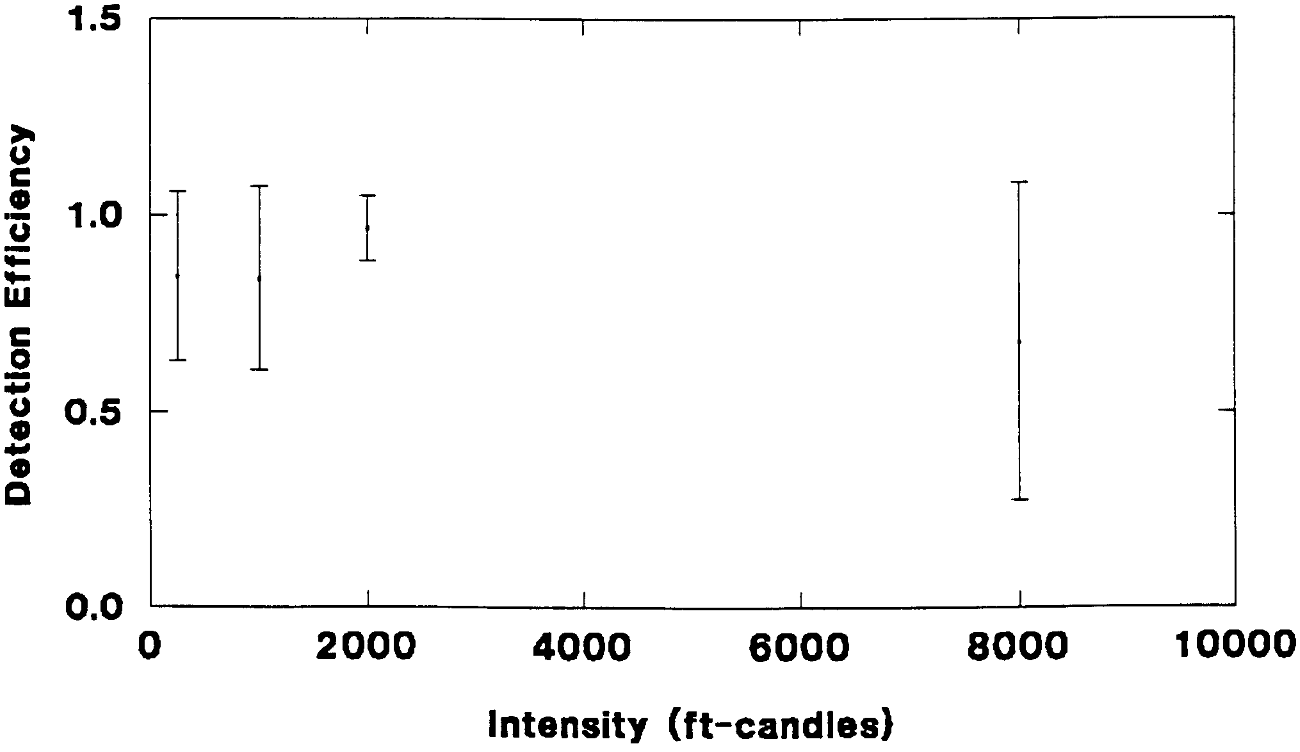

Figure 24. Effect of light intensity on detection efficiency using filter #107, light rose.

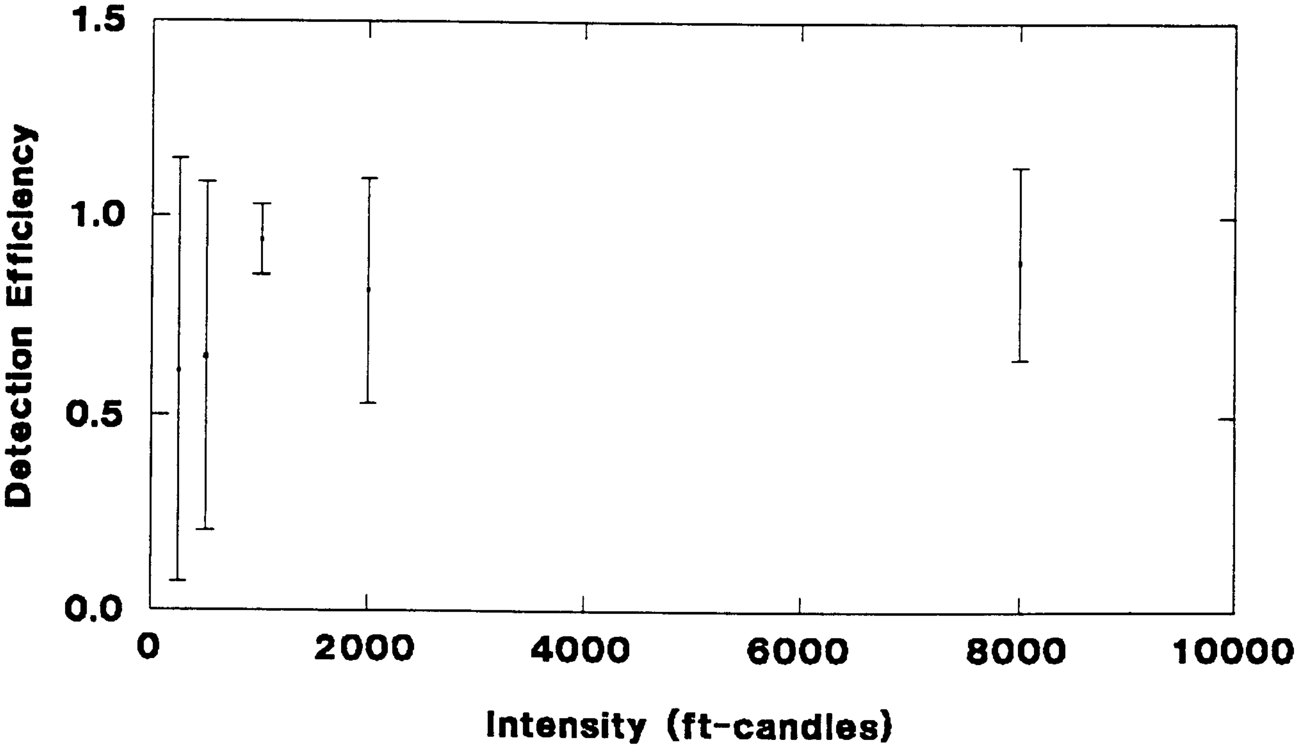

Figure 25. Effect of light intensity on detection efficiency using filter #110, middle rose.