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PIER LIGHTNG REQUIREMENTS TEST PROGRAM -- FINAL REPORT

ABSTRACT This report describes the methodology and results from a program of tests, and a survey of expert opinion to establish lighting criteria for Naval piers and adjacent water surfaces. This lighting is intended to contribute to the overall enhancement of pierside security, safety, and operations.

The report begins with a summary of the results of the program followed by the details of the methodology and data analysis employed. These details include background lighting principles, the test program plan and its execution, the quantitative data reduction, the methodology and results of the survey of expert opinion, and the interpretation of the test and survey results.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043

METRIC CONVERSION FACTORS

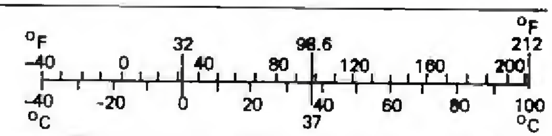
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH*		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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SECTION 1

SUMMARY AND CONCLUSIONS

Pier lighting may be justified only as a part of a security, operational, or safety upgrade program and then only up to an apparent maximum of 2 footcandles illuminance.

1.1 PROGRAM SUMMARY

The Navy Pier Lighting Requirements Test Program was initiated in San Diego on April 11, 1988 as Task ZZ19 of Contract N00123-86-0299 with Mission Research Corporation performing as a Subcontractor to Tecolote Research. This contractor team was directed by the Navy Civil Engineering Laboratory. The sponsorship of the program was provided by NAVFAC.

The program began in July 1986 as an outgrowth of Navy studies of pier modernization, including wider and multidecked piers. Increased terrorist attacks around the globe in the same time frame gave impetus to including security design criteria to the obvious operational and safety criteria. The lighting system to be tested was designed in March 1987 and contracted in September 1987. The initial test plan and plan of action were developed in 1987.

The program goals are to determine if existing Navy pier lighting guidelines are adequate and to discover if variations from such lighting guidelines will significantly improve or degrade productivity, safety, or security. The end product of this program is a quantitatively defensible and interdisciplinarily coordinated Navy pier lighting specification.

This program was divided into seven tasks as follows:

Task 1	Provide Revised Test Plan
Task 2	NAVSTA San Diego Logistical Coordination
Task 3	Passively Record Pier Operations
Task 4	Active Security Test
Task 5	Test Data Reduction

Task 6 Delphi Panel Data Interpretation

Task 7 Report and Lighting Specification

Original schedules anticipated completion of all these tasks by January 1, 1989, however construction delays caused a six month delay in most aspects of the program.

The emphasis of this program was to use a prototype lighting system installed on an operational Navy pier at NAVSTA San Diego to study the relationship between lighting and security, operations and safety. A large contingent of NAVSTA personnel were used as intruders and observers to provide nearly 8000 records of intrusion visibility on the pier surface as well as on the water surface surrounding the pier. An extensive CCTV instrumentation system was installed by the Naval Electronic System Engineering Activity (NESEA) to allow comparison of direct human observation with video monitoring, comparison of pier surface observation aspects with those at significant heights aloft, and measurement of operational timelines for ship mooring without contaminating the results by our presence. A panel of experts in operations, security, human factors, and safety was assembled to interpret the data. This group operated as a Delphi Panel, responding to a series of formal polls. Retired Rear Admiral Donald Iselin was also retained as a consultant to help interface with Naval personnel and organize the test program and Delphi survey.

1.2 PIER LIGHTING TEST CONCLUSIONS

1.2.1 Pier Security Conclusions

The test indicate that pier security is very dependent upon relocation of the security personnel from the pierhead. The pierhead location is *only* useful for entry control badge inspection. Any attempt to secure the pier surface from this location will prove unsatisfactory due to the daytime traffic obscuration and long distance to the end of the pier.

During the day, traffic on the pier, both vehicular and pedestrian, limit security observation of any intruder from the pierhead to around 45 percent maximum effectiveness. Also, even during daytime, the ability to observe the far end of the pier is reduced to less than 50 percent just due to the long distance of 1200 feet.

Day and night security is *dependent* upon multiple additional observer locations at higher points above the pier surface or at several points along their pier surface or at several points along the pier surface. Use of CCTV near the top of the 100 foot lighting masts, observers as high as practical on the moored ships, or several spots on their pier surface is crucial to achieving observation probabilities above 85 percent. The only way to see what is happening on the pier surface, is to look down on it or across it for limited distances. The current roving patrol has little or no bearing on the detection of intrusions due to his low altitude and his facing one way at any given moment. No amount of pier surface lighting can be justified for security until a commitment is made to relocate observers to new vantage points.

Even in the darkness, with lighting of 0.005 to 0.2 footcandles, detection reliability of rolling intruders is high if the observation distance is 600 feet or less. Detection at extreme distances of 1200 feet is unreliable no matter how much light is provided, even in daylight. In the intermediate distances where visibility is becoming marginal at around 900 feet, lighting appears to help detection reliability. There is no evidence that lighting levels over 2 footcandles are particularly beneficial. Lighting to 2 footcandles illuminance is probably the maximum which can be justified for pier security, and even then it is only beneficial if observation distances approach the limit of reliable human eyesight – around 900 feet in Navy pier situations.

The tested lighting system exhibited many of the features desirable in an operational system. While it is probably true that a single lighting mast in the middle of the pier is sufficient to support lighting, two or three masts are desirable to provide proper observer viewing in traffic and glare environments. As little as 38 percent of the tested luminaires are required to provide a very uniform 2 footcandles illuminance on the pier surface, if a low angle of incidence "glare lighting" approach is utilized.

The human factors aspects of the pier lighting test program were as important as expected. Security guards exhibited a wide range of performance reliability as anticipated. In daylight, detection scores for the same situation ranged from 100 percent to 0 percent. Physiology and psychology combine through eyesight and attentiveness variances to produce extreme differences in observation performance. In other words, we note that test results are dependent upon whether participants were alert and dedicated or asleep or in between. All security operational results will be similarly influenced by observer commitment, which will in turn be the result of training and rewards.

Data shows that CCTV generally requires higher levels of lighting than direct human observation.

The surface of Navy piers can be secured and lighting can play a role in achieving such a goal. One way to achieve a high level of pier security is for each moored ship to position a highly trained and motivated observer at the highest practical point on the ship's superstructure around the clock. This approach probably does not benefit greatly from lighting because such an observer is within 600 feet of all points of interest on the pier. Another way to achieve a high level of security is to place three masts evenly along the pier with lighting on the middle one providing 2 footcandles illuminance and CCTV on the two end masts to provide opposing views of the pier in traffic or glare situations. The difficulty with the latter concept will be reliably viewing the CCTV monitors. Computer processing the CCTV image for intrusion activity is unfortunately not a solution for Navy piers due to the high level of pier activity, particularly during the day. Other observer/lighting concepts deserve attention as well.

1.2.2 Water Security Conclusions

Water surface security is quite a different problem since it requires surveilling a large surface area instead of the long narrow zone so typical of most security situations. Nevertheless, the results of the water security test performed are quite similar to those for the pier surface.

The most important security feature in achieving high reliabilities of detection of swimmers on the water is proximity of the observer. Within 600 feet, the detection can be made equally reliably in the dark or during daylight. At the distances where visibility is marginal, around 900 feet, improved lighting appears to increase security detection reliability. Tested water surface lighting levels of 0.1 to 0.3 footcandles appear insufficient at observers locations around 900 ft. The appropriate levels are not known and more testing is required before a conclusive and cost-effective recommendation is possible, although 2 foot candles represents a likely upper bound.

As in the case of the pier surface, options appear to exist for placing observers high on the outer superstructure of moored ships. This places an observer within 700 feet of all water between the piers and may not even require lighting for achievement of high security observation reliability. Alternatively, one may structure a surveillance system around the same three pier masts supporting lighting and CCTV as outlined for the pier surface.

If lighting is used in this manner, a system very similar to that tested, with 60 percent of the luminaires directed toward the water will likely provide 2 footcandles on the water surface, and provide 85 percent visibility of swimmers at 900 feet.

1.2.3 Pier Operations Conclusions

Unfortunately, the plan to acquire quantitative data on the influence of lighting level on pier operational timelines was thwarted by various factors. In spite of videotaping Pier 5 continuously for almost two months, no night moorings were ever recorded.

In this regard no specific requests for night arrivals or departures were made by the project team. The concern was for tainting the human factors aspects of a "programmed" trial, if too many of the concerned personnel were aware of the purpose of such a trial.

The informal consensus of the shipboard and pierside operational personnel talked to during the tests did suggest, though, that lighting helps operations. "Comfort" levels were up when the pier was lit at night. Common sense also says lighting is more natural. The commercial sector is uniform in its application of lighting to similar situations.

While solid quantitative data stemming from the video recording is lacking on the relationship of pier lighting to pier operations, we do have some information.

One night mooring in the dark was witnessed by the test team during a site inspection well before any instrumentation was operational. This mooring is recalled as having been performed (lines within around 10 minutes, brow within 20 minutes, and electrical utilities within 40 minutes) roughly equal to daylight measurements by others. Another night mooring occurred on December 1 as security intrusions were being conducted under the glare lighting scheme of around 2 foot candles. Notes taken by the test team show lines within around 10 minutes and brow with 17 to 20 minutes.

Quantitative arguments supporting pier operational lighting are still lacking and qualitative arguments are inconclusive. For example, the above information shows very similar timelines in performing tasks in the dark without lighting compared to daylight timelines (as published in "Port systems Project Pier Utilization Study") – i.e., about 15 minutes to tie up. While visibility difficulties slowed electrical utility hookup somewhat, even these timelines were of the same order to those published for daytime. The likely truth is that the Naval personnel are so well trained at their duties and practiced at performing them in the dark that lighting does not materially help timelines.

It is also important to note the lack of demand for night operations. Over a period of more than 4 months, no significant level of night operational activity was observed on pier 5. Reports of periods of "high tempo" activity just were not seen. Another possibly important factor related to the ability of justifying pier lighting to support crane operations is the low predictability of the precise arrival and departure time of ships. This results in a crane waiting for 15 minutes to an hour in order to spend around 15 minutes setting brows and connecting electrical cables. This inefficiency dominates any possible efficiency resulting from improved lighting.

It is quite possible that pier lighting can be justified for the infrequent periods of intense activity or even wartime preparations with greater ease than it can for normal day-to-day activity. It is also possible that techniques other than lighting can independently or in conjunction with lighting result in operational improvements. An example of such a technique is the striping of utility cables and hoses with yellow reflecting tape or paint to aid in their night visibility.

1.2.4 Pier Safety Conclusions

As in the case of operations, no safety related incidents occurred during the test period and consequently no related quantitative data was obtained. This may be related to the fact (as suggested by available historical data) that although many potential dangerous situations exist, piers have proven to be relatively safe even in the dark due to the alertness and training of Naval personnel or because nighttime activities are limited . Also relevant is the fact that our presence was for only a relatively short period of four months.

These appears to be general and informal agreement by those talked to that no safety crisis or problem of major proportions exists on Naval piers, even in the dark. Central records of pier accidents provided us reveal some injuries and even deaths on Naval piers at night, but other dominant causes were common, including open manholes and drunkenness. One reasonable question is whether the pier is safer at night or during the day. On site experience leads test team members to suspect that daytime intermingling of heavy vehicular and pedestrian traffic is the highest risk environment. Separation of vehicular and pedestrian traffic could be readily accomplished by use of yellow painted walkways (that have currently been handled by a stripe that has faded) and by cones and plastic traffic tape. If such a daytime approach were adopted and lights were applied at night, visibility would be even more enhanced as compared to the current oil soaked pier surface.

Many unsafe practices are common; such as leaving black utility cables around on the pier, tying bicycles up on the pier, walking around in the midst of crane operations without any temporary barriers being used, and typically walking down the middle of the vehicular roadway. At night light clothes or reflective bands are not required on pedestrian traffic. Safety records speak well of the alertness and training level of Naval personnel, in relation to these practices. Lighting is likely to help and will never hurt safety statistics, but lighting should not be expected to solve a safety problem to the exclusion of these other safety practices.

1.2.5 Summary of Test Conclusions

Figure 1.1 summarizes the data obtained from this test program in the form of recommended pier surface and water surface illuminance versus observation distance. This graph is based upon a 90 percent likelihood of observing rolling and swimming intruders on the appropriate surface. As observation distance approaches 1200 feet, observation success cannot be assured with any lighting.

Given Figure 1.1, it is recommended that in situations where a single person must be applied to securing a pier, two to three 100 foot poles should be used to provide up to 2 footcandles illuminance on the pier surface and the water surface. These poles must serve as standards for the luminaires and CCTV cameras. Another lighting system for situations with constrained manpower is the placement of lights on the ship superstructure and use of CCTV cameras high on any docked ships to look fore and aft along the pier and out to the water surface.

Finally, in situations where Naval manpower is in plentiful supply, for example when 2 to 4 personnel per ship or 4 to 8 personnel per pier are available for pier surface security, reliance upon already available ambient lighting is possible. In such situations, one can place two personnel high on the superstructure of any ship located at the pier facing fore and aft to secure the pier. Two additional personnel can be placed outboard near the bow and the stern to secure the water surface again using ambient lighting. Existing techniques for lighting pier operations work effectively, although painting surfaces or use of reflective tape is recommended to highlight various pierside utilities.

1.3 PIER LIGHTING DELPHI SURVEY CONCLUSIONS

As part of this study a Delphi Survey of a panel of Navy experts was conducted. The Delphi Survey is a formal technique for eliciting and refining group judgments. The objective of applying this Survey Technique to the Pier Lighting Project

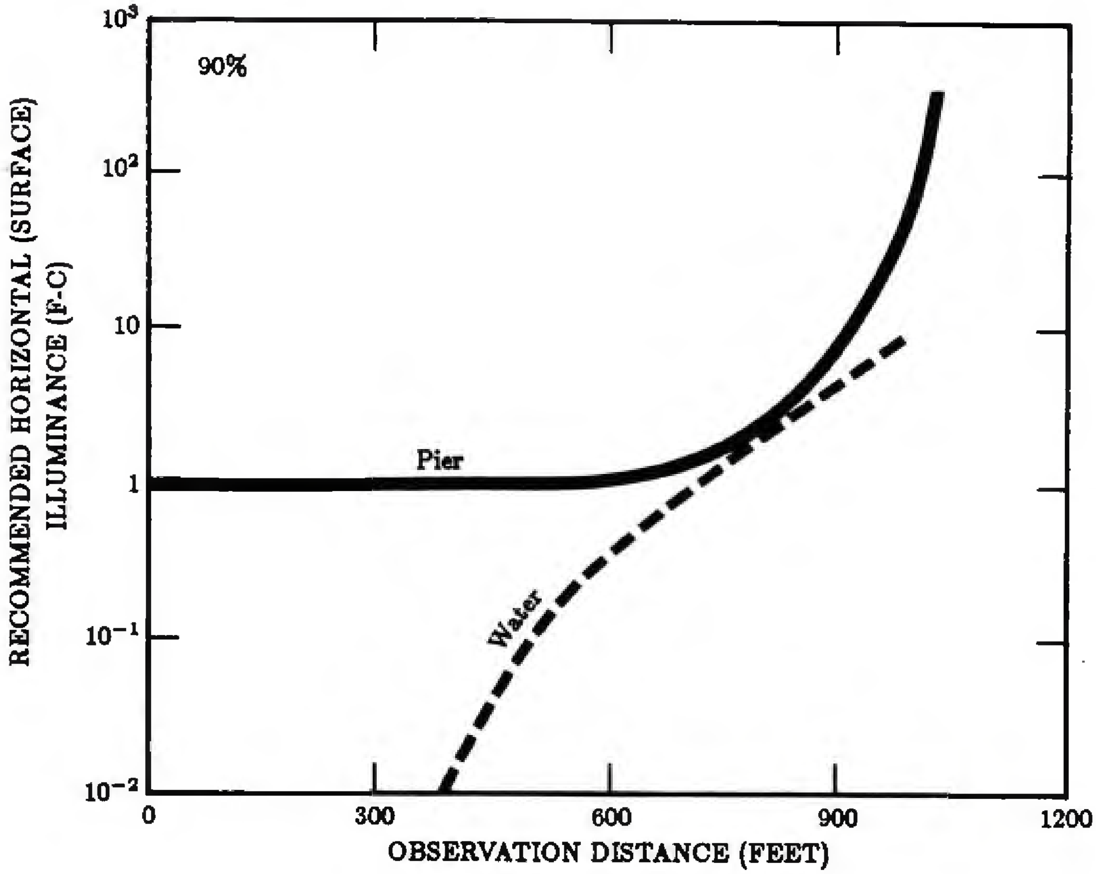

Figure 1.1. Recommended Lighting Illuminance.

was to identify important considerations related to lighting specifications for Navy piers considering pier security, operations and safety. The panel of experts assembled for this purpose represented a broad spectrum of related knowledge and experience and are identified in Section 5.

In general a Delphi Survey is most appropriate in situations where because of the inherent nature of the problem and/or because of limited resources, it is not possible to *quantitatively* establish objective and measurable relationships between the various factors effecting a problem area. In such situations one must rely on the judgement of experts who are familiar with and who have dealt with the various aspects of the problem. The distinguishing features of the Delphi Survey described in Section 5 are:

1. Anonymous response of a Panel of experts to a formal questionnaire.
2. Iterations and controlled feed back.
3. Statistical presentation of the results.

The Delphi survey conducted as part of this study resulted in the following general conclusions:

Security Threat. The most critical pierside threat is considered the walking threat, followed by running or crawling. The more critical water threat is considered the swimmer followed by a boat.

Security Guard Observer Location. For lights located on the pier, a roving guard on the pier is preferred. For lights on the ship, a guard on the bridge of the ship; and for lights located underwater, a guard on the fantail/forecastle of the ship is preferred.

Safety/Operational Activities Improved By Lighting. Pedestrian traffic followed by crane operations are the pierside activities considered to be most improved by lighting.

Fixture Location. The pier surface is preferred when considering both security as well as safety and operations. Security considerations also give preference to a location underwater next to the pier for water threats.

Fixture Height. For lights on the pier there is a preference for 100 ft above the pier surface. This is the case considering both security as well as safety and operations.

Pole Spacing. 630 ft is preferred considering security, operations and safety factors.

Amount of Lighted Area. For lights shining on the pier, all of the pier surface is preferred when considering security, safety and operational factors. For lights shinning on the water, the full surface of the water between the piers is preferred.

Light Intensity. 2 ft-candles is preferred as a balance between security, safety and operational factors.

Time Lights Are On. 100% is preferred for security. Up to 10% is indicated for most operational activities with the exception of vehicle transport and pedestrian traffic where 50% of the time is indicated.

Spectrum Options. High pressure sodium is preferred under all conditions.

Pier Surface Reflectivity. Intermittent beaded stripes of retro- reflectors across the pier (i.e., like highway lane dividers) is the first choice for security, with gray as a second choice. Gray is preferred for safety and operations.

1.4 RECOMMENDED PIER LIGHTING CRITERIA

Table 1.1 provides a recommended lighting specification for Navy piers based upon this program. The maximum specifications are for operation, safety and/or security with observers over 600 feet away. The minimum specification is for security only with observers at or under 600 feet away.æ

Table 1.1. Navy Pier Lighting Criteria.

FACTOR	FOR SECURITY ONLY WITH OBSERVERS AT OR UNDER 600 FEET	FOR OPERATIONS, SAFETY AND/OR SECURITY WITH OBSERVERS OVER 600 FT. AWAY	VARIANCE
ILLUMINATION LEVEL			
• PIER SURFACE	0.02 FC	2.0 FC	± 50%
• WATER SURFACE	0.005 FC	2.0 FC	± 50%
• VERTICAL SURFACE	0.02 FC	2.0 FC	± 50%
SPECTRUM	HPS	HPS	NA

NA = Not Applicable

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SECTION 2

BACKGROUND LIGHTING PRINCIPLES

This section will provide the background for understanding the test plan. It provides, as a point of comparison, lighting standards for piers and other analogous working environments. It discusses the role of lighting in security. It discusses visibility theory as it relates lighting to human vision. This section also provides background on lamps and luminaires, as well as video surveillance.

2.1 IES STANDARDS

The Illumination Engineers Society (IES) lighting handbook provides quantitative standards for lighting based upon qualitative judgments. Categories of interest here include:

cargo handling and port shipping

security

outdoor

underwater

aviation

2.1.1 Operations

The IES Lighting Handbook 1981 Application Volume, pages 2-15, recommends pier illuminance values of:

Freight piers:	200 lux	(20 foot candles)
Passenger piers:	200 lux	(20 foot candles)
Active shipping surrounds area:	50 lux	(5 foot candles)

The same reference discusses Cargo Handling and Port Shipping facilities on pages 9-24 and recommends illuminance values of between 20 lux (2 foot candles) for crane operations to 5 lux (0.5 foot candles) for most pier and warehouse operations.

Airports use high mast floodlighting to provide illumination of aircraft stand/apron/ramp areas. The recommended levels, from pages 15-15 of the same reference are 20 lux (2 foot candles).

2.1.2 Safety

The same IES reference provides safety standards on page 2-45. These are:

High Hazard/High Activity	54 lux	(5 footcandles)
High Hazard/Low Activity	22 lux	(2 footcandles)
Low Hazard/High Activity	11 lux	(1 footcandle)
Low Hazard/Low Activity	5.4 lux	(0.5 footcandles)

2.1.3 Security

The IES reference discussed security surveillance lighting of large open areas and recommends:

Average illuminance	2 lux	(0.2 footcandles)
Minimum illuminance	0.5 lux	(0.05 footcandles)

During the Lighting and Artificial Surface Technology program sponsored by the U.S. Army MERADCOM, illuminances tested in a perimeter fence zone involved 2 to 0.2 footcandles for broadside floodlighting of natural grass surfaces under HPS luminaires.

2.2 SECURITY PRINCIPLES

2.2.1 Threats

There are many ways of dissecting the threat spectrum. It may be divided into levels of severity, ranging from civil disobedience to paramilitary attack. A list of threats that represent increasing levels of severity might look like:

civil disobedience

criminal

terrorist

enemy distant attack

An important difference between the first two and the last two such categories is the difficulty or impossibility of deterring the last two. The last two typically attack with full recognition of life risk. The lower on the list, the greater the degree of dedication, weapon firepower, and strategy planning generally exhibited.

Threats, particularly severe ones, will choose logically between overt and covert tactics. Diversionary attacks, use of military uniforms, use of Coast Guard look alike boats and similar tactics will be considered by severe threats. Observation of target operations and weakness has been known to occupy terrorist organizations for over 6 months. Severe threats generally attack with superior firepower, using truck bombs, mortars, light anti-tank weapons (LAWs), etc. and exhibiting a willingness to kill defenders at the initiation of attack. While slow meticulous threats might offer a chance of avoiding detection by defenders, fast surprise strikes offer the chance of catching defenders off guard and unprepared for rapid reaction. Divers and swimmers might be representative of the former threat tactics, while hang gliders, helicopters and fast boats might be representative of the later threat tactics.

Some threats therefore stress the detection of attack while others stress the intensity and quickness of response. Lighting can play a role in deterring lesser threats, aiding detection and facilitating response.

2.2.2 Deterrence

The central principles of civil security are ones of deterrence and loss limiting. This recognizes that one need only raise the apparent risk to the threat beyond that at alternative target and that security above a certain level is not economically justified relative to the losses expected. These principles lead to urban street lighting, police patrol cars, night guards and receptionists, bars on windows and alarm systems on doors and windows.

As we focus upon lighting for deterrence, we are led to consider the psychological effect on threat tactics. Floodlighting is argued to be of deterrent value in civil and commercial areas for criminal threats. There has been no quantitative research in these areas of dynamic lighting. Dynamic lighting embraces lights that are turned on and off either randomly or under control of a sensor after detection. Whether using floodlights or spotlights, dynamic lighting would appear to a threat as representing a degree of preparedness and attentiveness that static lighting would not. Even random dynamic lighting could be used to help direct an observer guard's attention to various zones, avoiding inadvertent over attention to one zone.

While dynamic lighting techniques might be superior to static floodlighting for deterrence, terrorist and sabotage threats are unlikely to be deterrable under any circumstances. In practice it is not obvious whether a serious attack would be more likely during daylight, static night flood lighting, dynamic night lighting, or in darkness with observation by infrared imaging.

2.2.3 Role of Intrusion Detection Systems (IDS)

Intrusion Detection must be related to barriers and response. The central issue in enforceable security is the comparison of the threat and defense timeline. From the time of a response force alarm receipt to engagement of the threat before successful attack of the target is the response timeline. It must be shorter than the threat timeline from the same alarm point to the mission completion. Often this requires not only a dependable Intrusion Detection System (IDS), but also the detection of the threat at a distant perimeter and use of delaying barriers after detection.

Usually, we also distinguish between detection and assessment of the threat. Detection is the first indicator that something might be happening. This is often performed by an electromagnetic sensor and is used to "wake up" a guard or turn on another sensor to determine if it is a nuisance alarm or an actual attack warranting response alarm. The subsequent assessment is frequently performed by a roving patrol or fixed observer and sometimes assisted by aids such as CCTV.

Our testing does not attempt to measure detection since that process is dominated by human behavioral issues of attentiveness, motivation, fatigue and others. The test plan focuses upon assessment, which is a more mechanical capability.

Many, if not most military security arrangements utilize a perimeter detection principle in an attempt to help the timeline. These deployments use perimeter fencing, illuminated at night and augmented with electromagnetic sensors. The sensors alarm with relatively high frequency due to environmental difficulties such as wind, rain, animals and so on. As the sensors alarm, a guard usually high in a tower is alerted to examine the perimeter zone in question for activity. If activity were noted, a response team would be called to intercept the threat. An analogous system at NAVSTA San Diego would probably use a light beam across the water between the ends of the piers to turn on spotlights and be examined by a pierside guard or by CCTV.

From purely a security point of view there are several, if not many lighting concepts using perimeter spotlighting, underwater and under-pier lighting, infrared or low light level vision devices, as well as floodlighting that warrant comparison. However, the floodlighting concept is one offering unique side effects for enhancing pier operations and safety.

2.3 VISIBILITY

This section will discuss how the human eye and mind use light to observe events. It will introduce lighting theory and principles and introduce the lighting concepts to be examined in this test program. This section is completely extracted from the previous report, "Lighting and Artificial Ground Cover".

2.3.1 Photometrics

Figure 2.1 indicates the relationship between various photometric units.

Luminous flux is the total light from a source measured in lumens with a sensor spectrally matched to the average human eye. The candle in Figure 2.1 emits 4π lumens.

Intensity is the luminous flux through a unit of solid angle and is usually measured in candelas (lumens/steradian).

Intensity (I) 1 lumen/steradian = 1 candle = 1 candle power = 1.02 candelas

Illuminance is the amount of luminous flux received by a unit of surface area and is usually measured in footcandles (lumens/ft^2). Illuminance values for normal outdoor light levels are shown in Figure 2.2.

Illuminance (E) lumens/cm^2

1 lumen/m^2 = 1 meter candle = 1 lux

1 lumen/ft^2 = 1 ft-candle (ft-c)

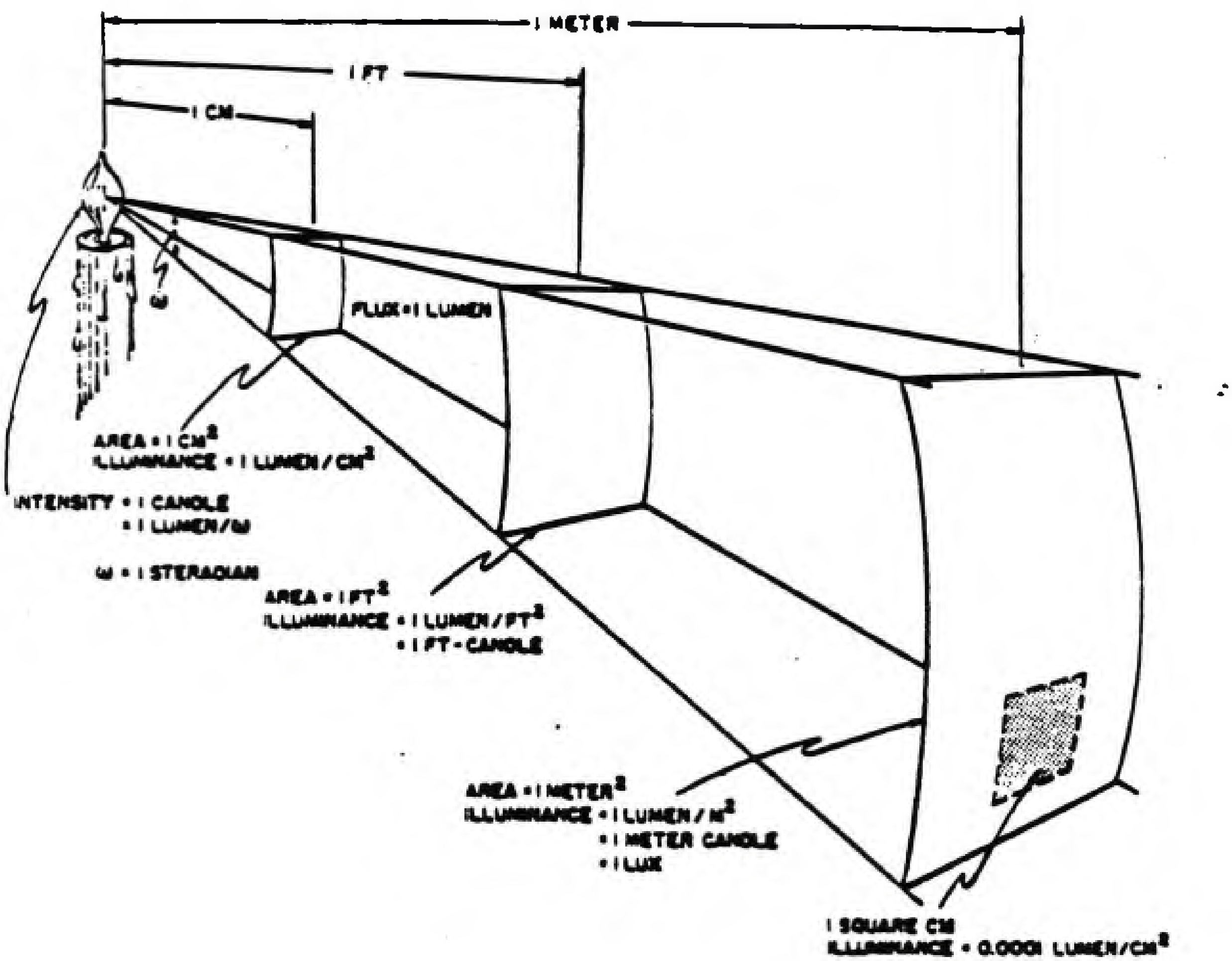


Figure 2.1. Intensity and Illuminance Units.

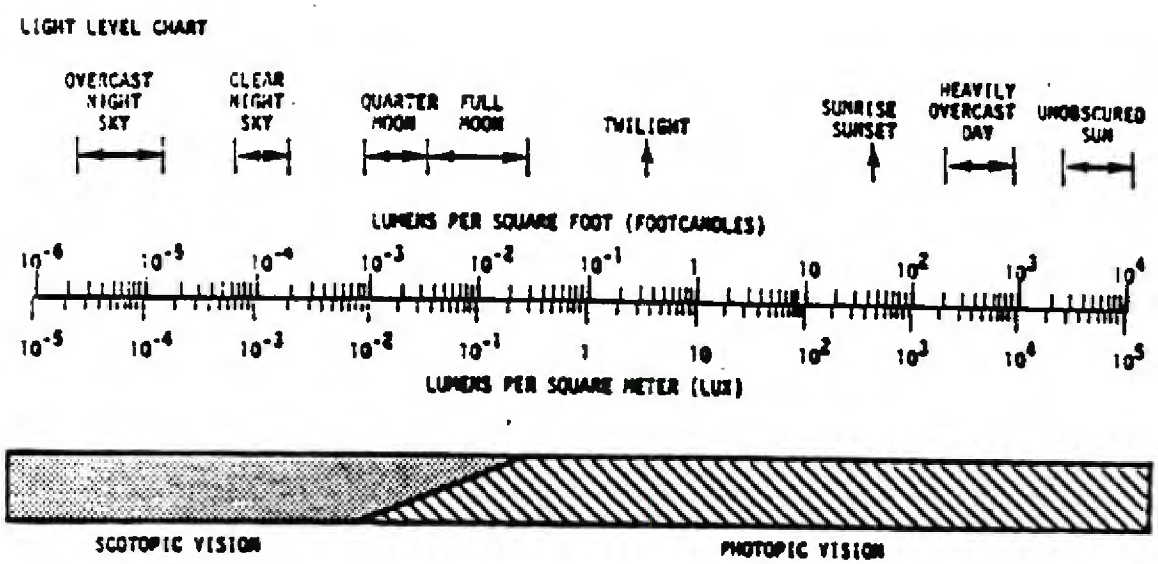


Figure 2.2. Light levels encountered in the natural environment.

Luminance is the amount of light emitted or scattered by a surface and is usually measured in foot-lamberts. One footcandle falling upon a perfectly diffusing white surface with no loss would produce one foot-lambert.

Luminance (B) lumens/steradian/m^2 (or cm^2)
lamberts (L) = millilamberts (mL) x 10^3 =
micro lamberts (μL) x 10^6
For a perfectly diffusing surface, 1 lambert =
$1/\pi$ candles/cm^2 foot-lambert (ft-L) = 1.076 mL

Many other strange units exist, but are seldom used (thank goodness). These include brils, brills, nox, stilbs, blondels, glims, apostilbs, Hefnerkerze, phots, scots, skots, helios, lumergs, pharos and Talbots.

Table 2.1 allows conversion of luminance units (and some illuminance units to illuminance assuming a lambertian surface).

2.3.2 Vision

The innermost lining of the eye is the retina. The retina, which in its construction is an extension of the brain, contains a very large number of very small light receptors called, because of their shapes, the rods and the cones as shown in Figure 2.3. There are some seven million cones contained almost entirely within the central portion of the retina, called the fovea as shown in Figure 2.4. The cones perform the function of precise sight at normal brightness levels. The cones are also color sensitive so that color vision is most acute on the central line of sight.

The other approximately 130 million rods are distributed more widely about the periphery of the eye; they are not color sensitive but have an extremely high sensitivity to light, so that their function is to permit seeing at very low levels of light. The relative sensitivity of rod vision is shown in Figure 2.5. The rods are far less closely packed than the cones; as a result the resolution of detail by rod vision is much less precise than with cone vision. In other words, the eye sees best centrally in bright light, its resolution is very high and it sees color. In the near-dark, resolution is poor, little or no color is seen, and vision is best in the periphery of the eye or when one looks slightly to the side of an object.

The cones are connected to the visual centers of the brain by a direct one-to-one link. The rods are linked in groups to a single nerve path. As a consequence, peripheral vision is less acute (less able to discriminate fine detail), because not only

To obtain number of ↓	Multiply number of → By ↘	Stilb	Lambert	Candle/in.²	Candle/ft²	Footlambert	Millilambert	Nit	Apostilb	Millifootlambert	Microlambert	Microfootlambert	Micromillilambert	Micromicrolambert
Stilb	Candle/cm²	1	3.183×10^{-1}	1.550×10^{-1}	1.076×10^{-3}	3.426×10^{-4}	3.183×10^{-4}	10^{-4}	3.183×10^{-5}	3.426×10^{-7}	3.183×10^{-7}	3.426×10^{-10}	3.183×10^{-10}	3.183×10^{-13}
Lambert	Lumen/cm²	3.1416	1	4.869×10^{-1}	3.382×10^{-3}	1.076×10^{-3}	10^{-3}	3.1416×10^{-4}	10^{-4}	1.076×10^{-6}	10^{-6}	1.076×10^{-9}	10^{-9}	10^{-12}
	Candle/in.²	6.452	2.054	1	6.944×10^{-3}	2.210×10^{-3}	2.054×10^{-3}	6.452×10^{-4}	2.054×10^{-4}	2.210×10^{-6}	2.054×10^{-6}	2.210×10^{-9}	2.054×10^{-9}	2.054×10^{-12}
	Candle/ft²	9.290×10^{2}	2.957×10^{2}	1.440×10^{2}	1	3.183×10^{-1}	2.957×10^{-1}	9.290×10^{-2}	2.957×10^{-2}	3.183×10^{-4}	2.957×10^{-4}	3.183×10^{-7}	2.957×10^{-7}	2.957×10^{-10}
Footlambert	Lumen/ft²	2.919×10^{3}	9.290×10^{2}	4.524×10^{2}	3.1416	1	9.290×10^{-1}	2.919×10^{-1}	9.290×10^{-2}	10^{-3}	9.290×10^{-4}	10^{-6}	9.290×10^{-7}	9.290×10^{-10}
Millilambert		3.1416×10^{3}	10^{3}	4.869×10^{2}	3.382	1.076	1	3.1416×10^{-1}	10^{-1}	1.076×10^{-3}	10^{-3}	1.076×10^{-6}	10^{-6}	10^{-9}
Nit	Candle/m²	10^{4}	3.183×10^{3}	1.550×10^{3}	1.076×10	3.426	3.183	1	3.183×10^{-1}	3.426×10^{-3}	3.183×10^{-3}	3.426×10^{-6}	3.183×10^{-6}	3.183×10^{-9}
Apostilb (asb)	Lumen/m²	3.1416×10^{4}	10^{4}	4.869×10^{3}	3.382×10	1.076×10	10	3.1416	1	1.076×10^{-2}	10^{-2}	1.076×10^{-5}	$\times 10^{-5}$	10^{-8}
Millifootlambert		2.919×10^{6}	9.290×10^{5}	4.524×10^{5}	3.1416×10^{3}	10^{3}	9.290×10^{2}	2.919×10^{2}	9.290×10	1	9.290×10^{-1}	10^{-3}	9.230×10^{-4}	9.290×10^{-7}
Microlambert		3.1416×10^{6}	10^{6}	4.869×10^{5}	3.382×10^{3}	1.076×10^{3}	10^{3}	3.1416×10^{2}	10^{2}	1.076	1	1.076×10^{-3}	10^{-3}	10^{-6}
Microfootlambert		2.919×10^{9}	9.290×10^{8}	4.524×10^{8}	3.1416×10^{6}	10^{6}	9.290×10^{5}	2.919×10^{5}	9.290×10^{4}	10^{3}	9.290×10^{2}	1	9.290×10^{-1}	9.290×10^{-4}
Micromillilambert		3.1416×10^{9}	10^{9}	4.869×10^{8}	3.382×10^{6}	1.076×10^{6}	10^{6}	3.1416×10^{5}	10^{5}	1.076×10^{3}	10^{3}	1.076	1	10^{-3}
Micromicrolambert		3.1416×10^{12}	10^{12}	4.869×10^{11}	3.382×10^{9}	1.076×10^{9}	10^{9}	3.1416×10^{8}	10^{8}	1.076×10^{6}	10^{6}	1.076×10^{3}	10^{3}	1

Example: X Footlamberts = X × 3.426×10^{-4} Stilbs

Table 2.1. Conversion factors for luminance units.

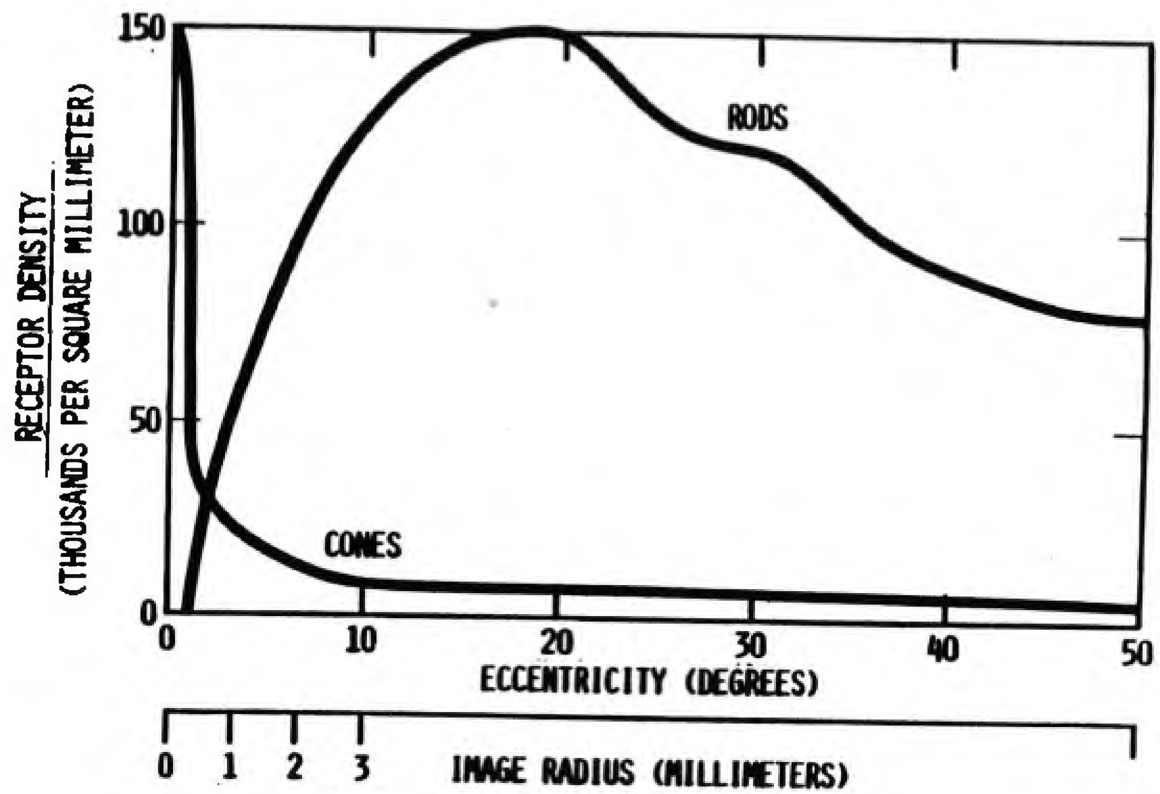


Figure 2.3. Spacial Sensitivity.

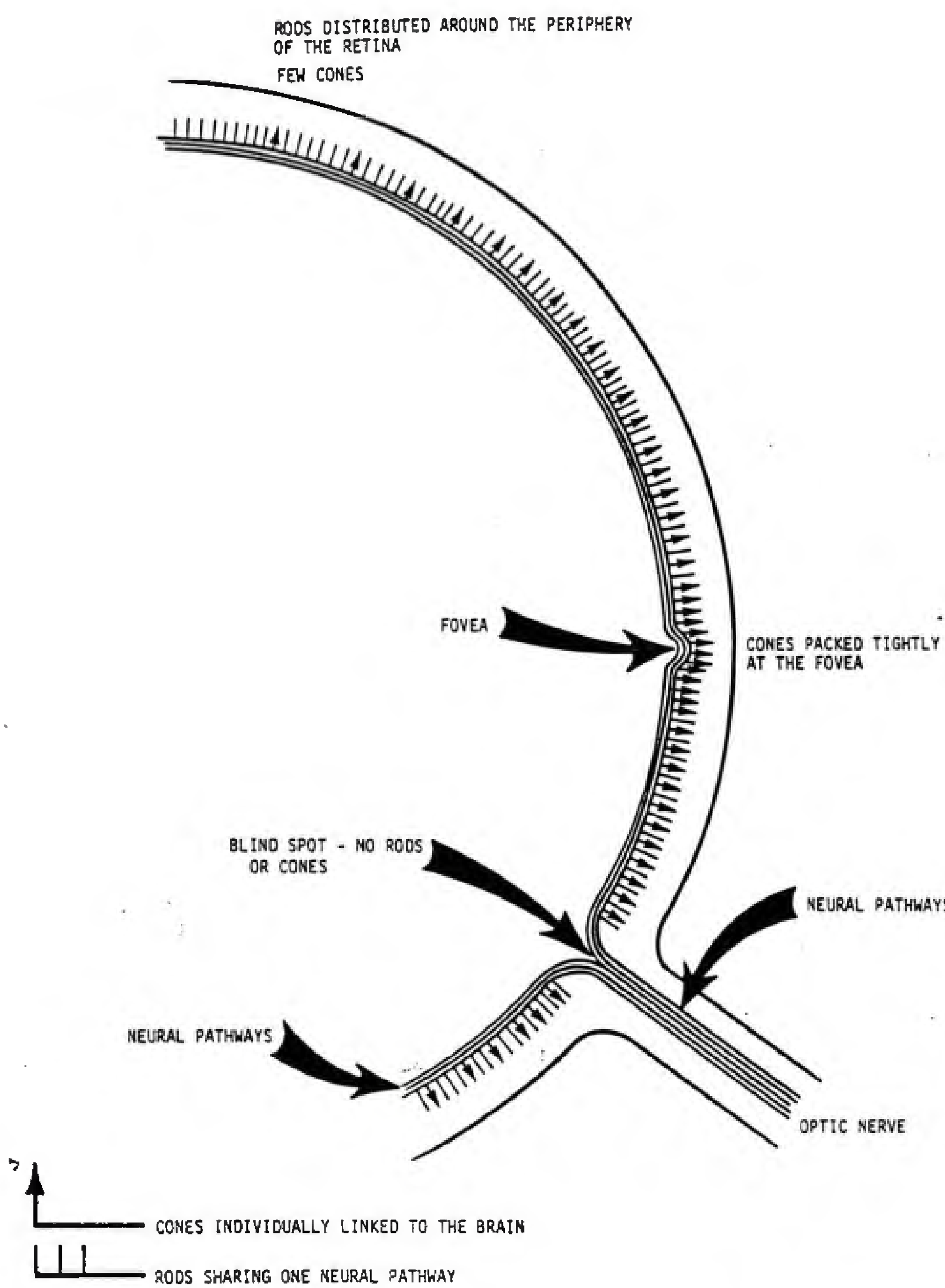


Figure 2.4. Schematic diagram of the cross-section of the retina. (Lighting and Seeing).

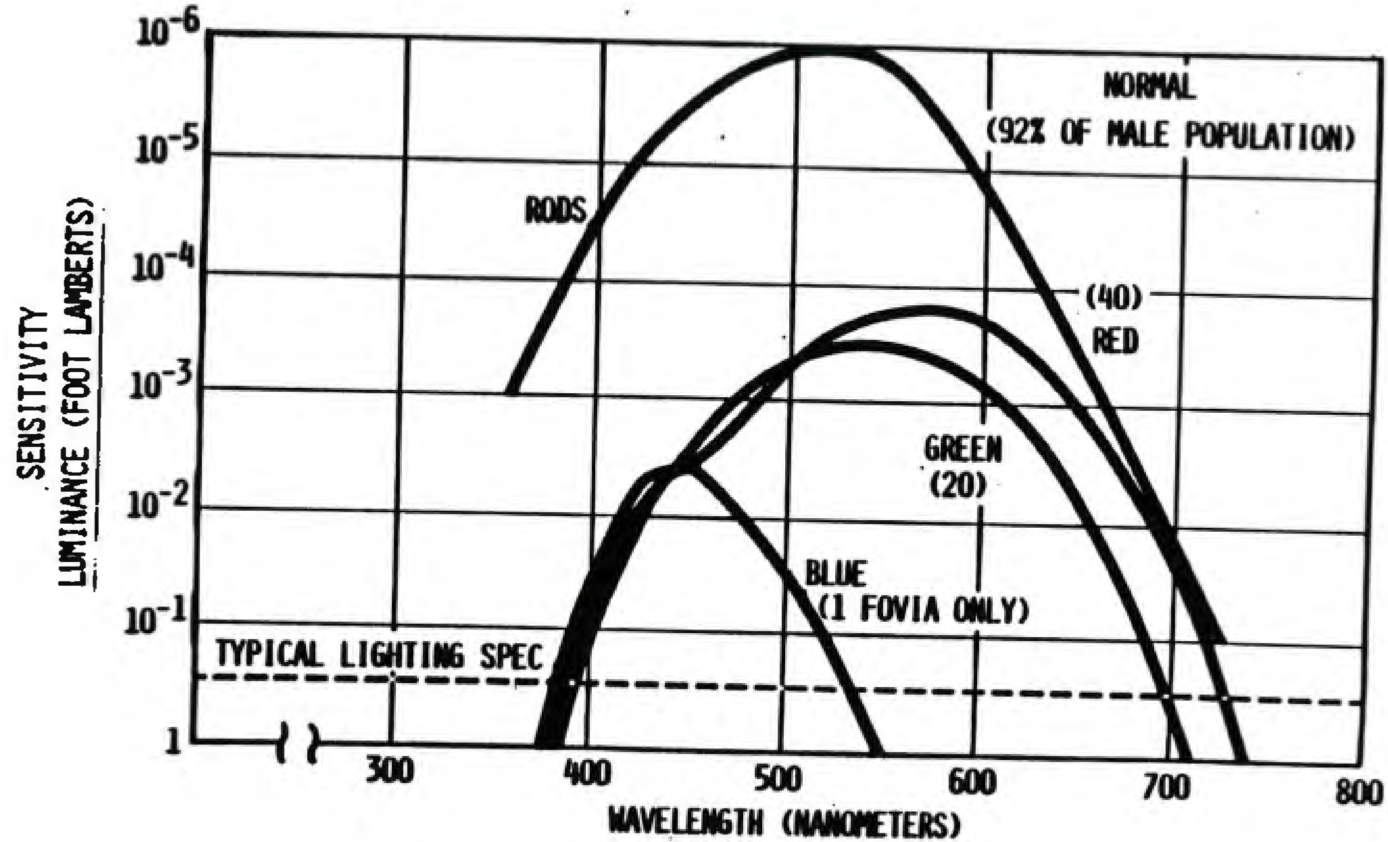


Figure 2.5. Spectral Sensitivity.

are there fewer retinal receptors (rods) per unit area, but those that are there are not connected singly to the brain.

As indicated in Figure 2.5, the cones are most sensitive in the yellow (600 nm) portion of the spectrum (resulting in the attractiveness of sodium lamps). The sensitivity results from the fact that there are 20 and 40 green and red cones for every blue cone in the normal population. The rods are most sensitive to the blue-green color (which is why we use red lamps to protect night vision). The eye adjusts slowly to large changes in light intensities. This aspect is called adaptation time and is illustrated in Figure 2.6. Car headlights or cigarette lighters can cause temporary "blindness" in security guards at night. As eyes age, the lens transmissivity decreases as a result of prolonged exposure to ultraviolet sunlight. Figures 2.7 and 2.8 show this effect, which is most pronounced in the blue end of the spectrum (under 500 nm). Nicotine affects the eye pupil and other drugs affect vision significantly. Smoking by participants must be controlled, and antihistamines and other drugs prohibited if results are to be believed.

2.3.3 Contrast

The visibility of a target against a background is dependent upon the target size and speed, and the target contrast ratio. In the absence of color differences, contrast is defined as the luminance (brightness) difference between a target and its background divided by the luminance of the background. That is,

$$C = (L_t - L_B)/L_B \tag{2.1}$$

where

C = target contrast
L_T = target luminance
L_B = background luminance

From the definition of contrast, we see contrast can either be positive (a bright target) or negative (a dark target).

A second term, visibility, is defined as $V = C/\bar{C}$, where C is the target contrast given in 2.1, and $\bar{C}$ is a threshold contrast labeled VL1 in Figure 2.9. $\bar{C}$ is determined experimentally by reducing the difference between target and background

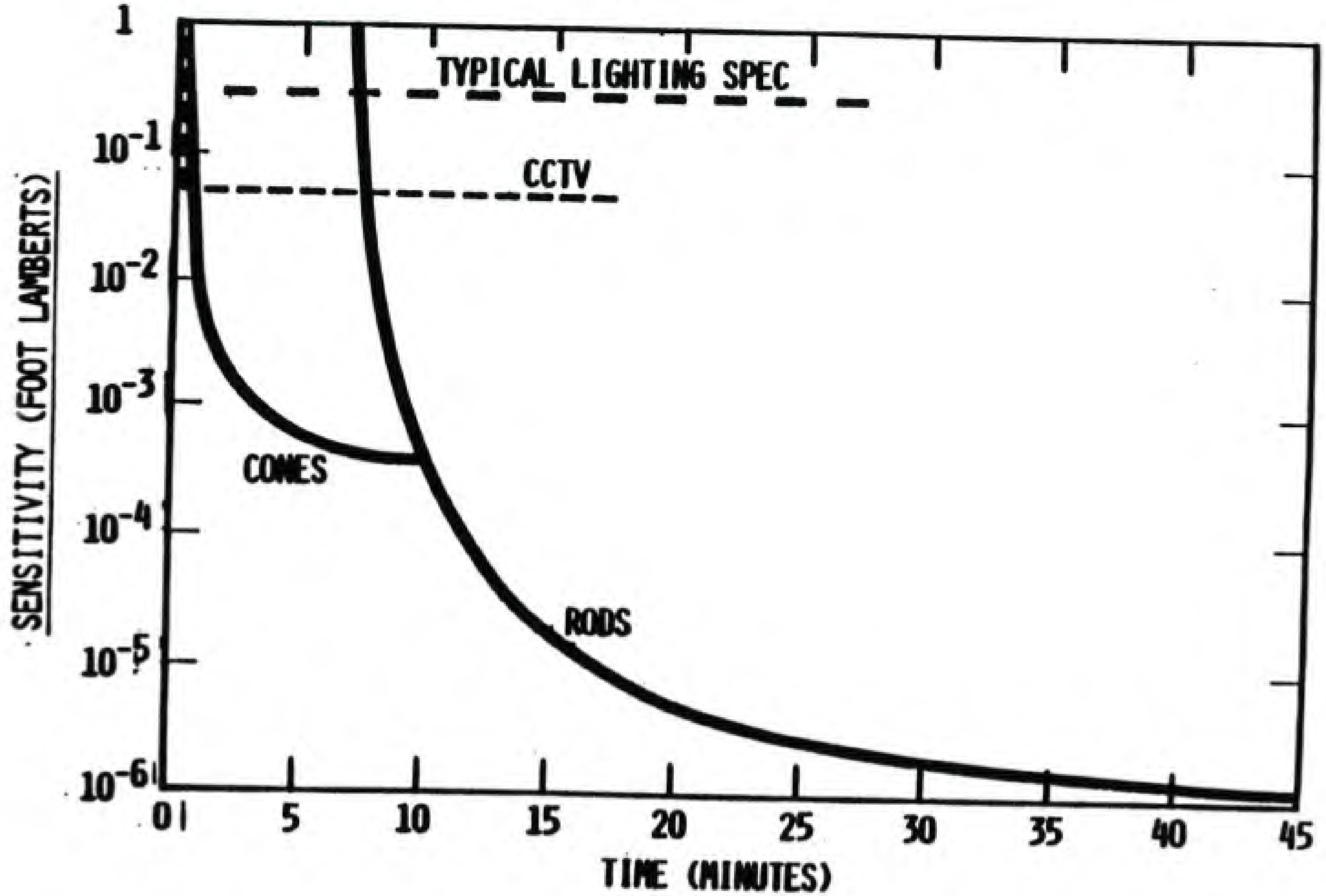


Figure 2.6. Adaptation.

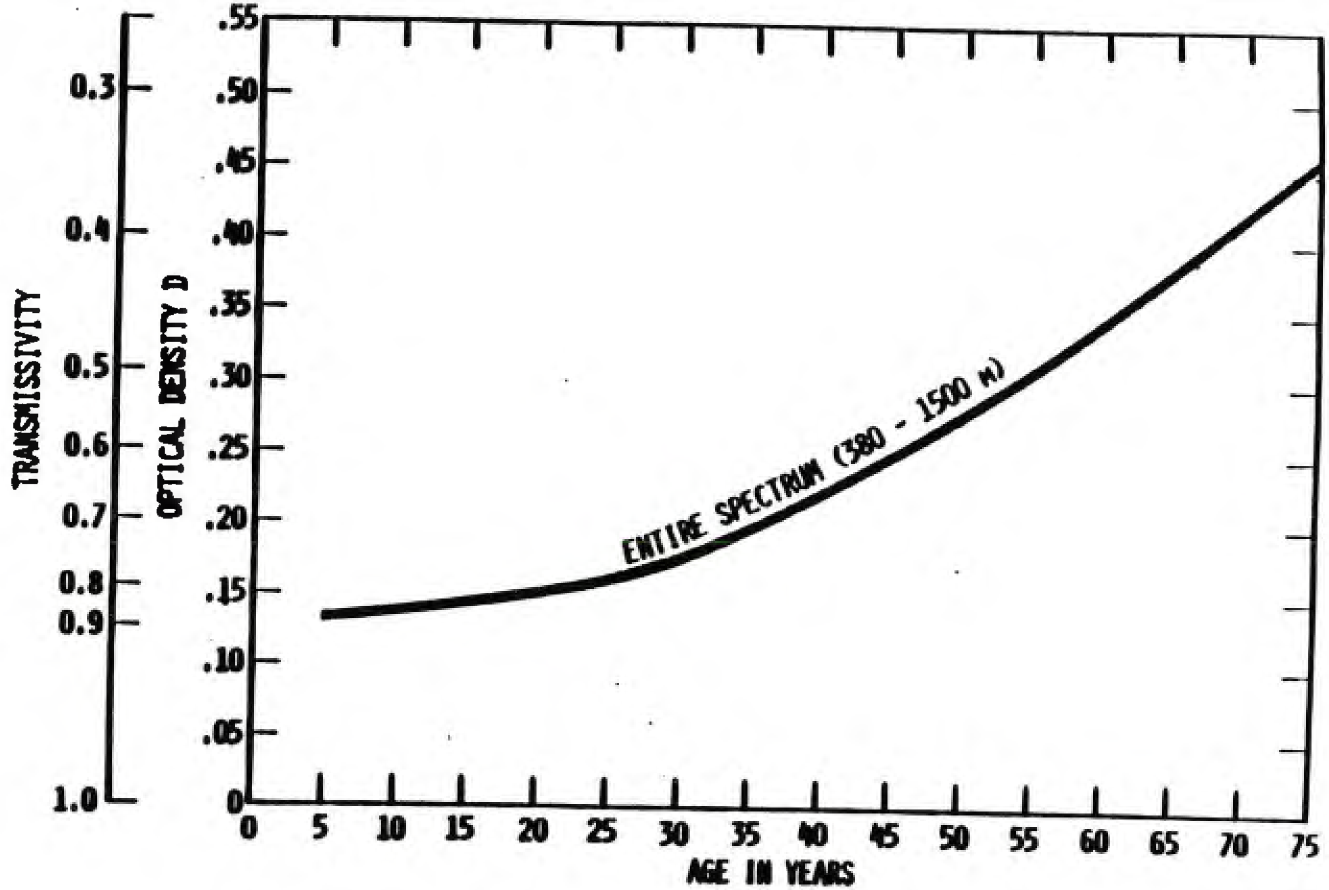


Figure 2.7. Eye degradation with age.

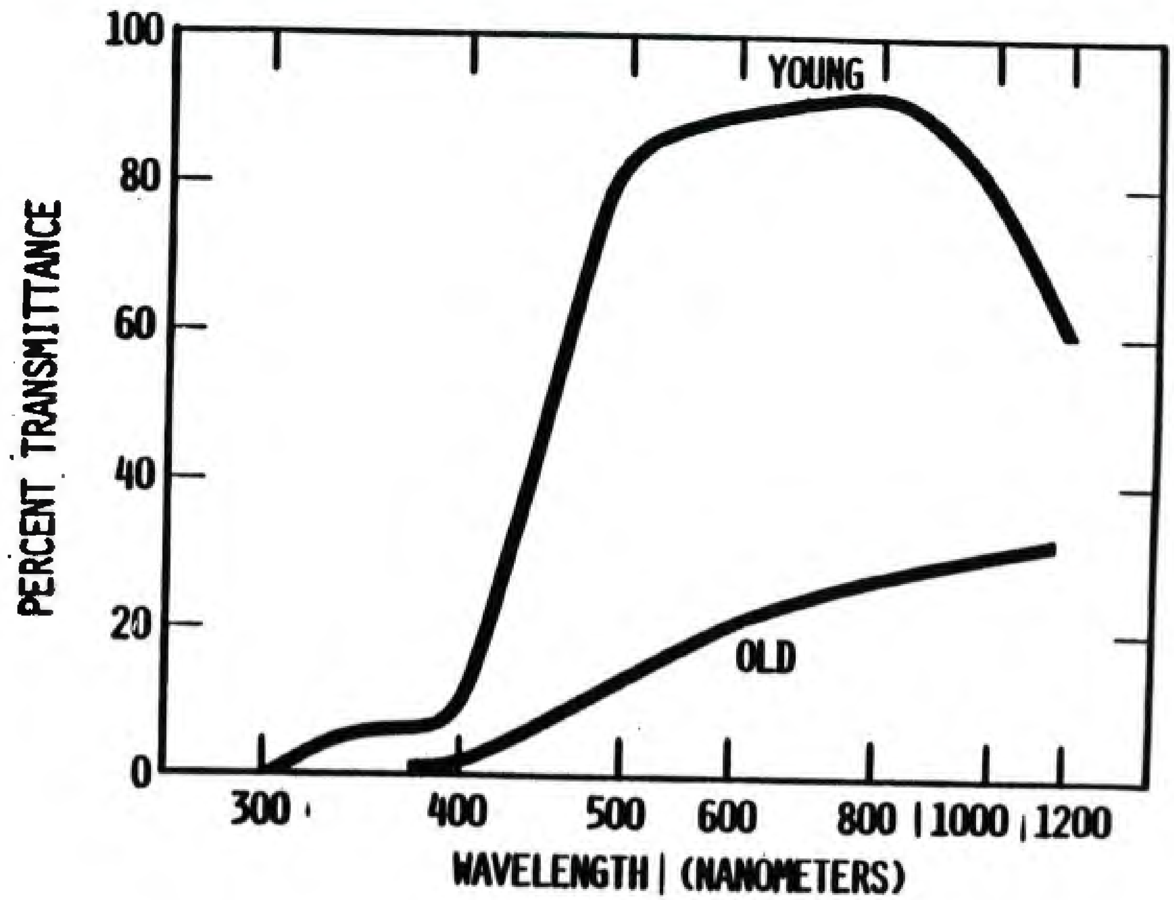


Figure 2.8. Aging loses blues.

luminances until the target is barely visible (nominally, detectable 50 percent of the time). Contrast as defined, is independent of illuminance when illuminated by a single source and could be written

$$C = (R_T/R_B) - 1 \tag{2.2}$$

where the Rs are reflectances in the direction of the observer (again assuming that the target and background have the same wavelength dependence).

There, curve VL1 in Figure 2.9 is used as a standard in the lighting industry. It is the visibility level at which an average young adult has a 50:50 chance of detecting a moving disk subtending 4 minutes of arc at the observer's eye when the disk is exposed for one-fifth of a second at a known location in a large field under fully diffused light. The data are taken in the absence of veiling glare or luminance.

Curves parallel to VL1 represent suprathreshold visibility. The VL number for any curve is the contrast multiplier used to obtain the curve from the VL1 curve. Contrast multipliers are chosen to represent the difficulty and requirements of defined visual tasks.

The VL8 curve is the 99 percent confidence of seeing a similar static target at an unannounced location in the scene. It has been shown that a contrast multiplier of 2.78 compensates for the differences between static and dynamic presentations of the same task. A factor of 1.5 compensates for the difference between not knowing and knowing where and when a task will appear. A factor of 1.9 converts to 99of these factors converts VL1 curve to a VL8 curve.

Figure 2.10 shows the effect of target size on required contrast ratio. A one foot diameter target at 800 foot range is around 4 minutes of arc. Thus, a swimmer's head is around 5 minutes of arc at the opposite pier and about 2 minutes of arc as viewed from the quay wall to a point 350 feet outside the pier end.

The data from which Figure 2.9 was derived were based on a specific task; detection of a disk of specified size against a uniform background when exposed for a short period of time. This task is not a very good analogy of the surveillance task. However, the curves present data on the manner in which visibility varies with contrast and background brightness, thus providing a basis for estimating changes of visibility.

Under normal circumstances, higher contrast ratios are obtainable for positive than negative contrast. Unless an intruder takes special precautions, his albedo (the ratio of scattered light to incident light) will be of the order of 0.2 with highlights up to 0.5 or greater. Thus, as seen against a black surface, such as asphalt (albedo

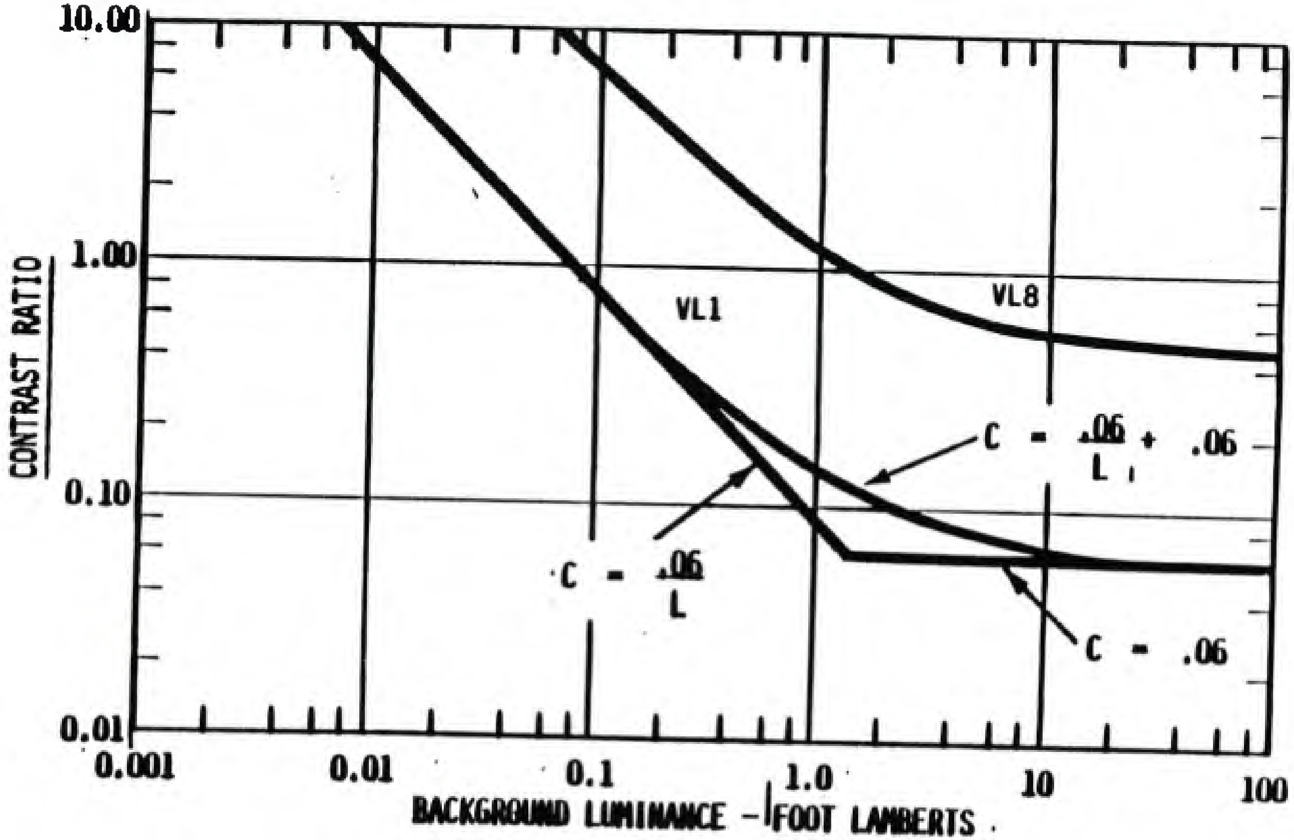


Figure 2.9. Visibility levels.

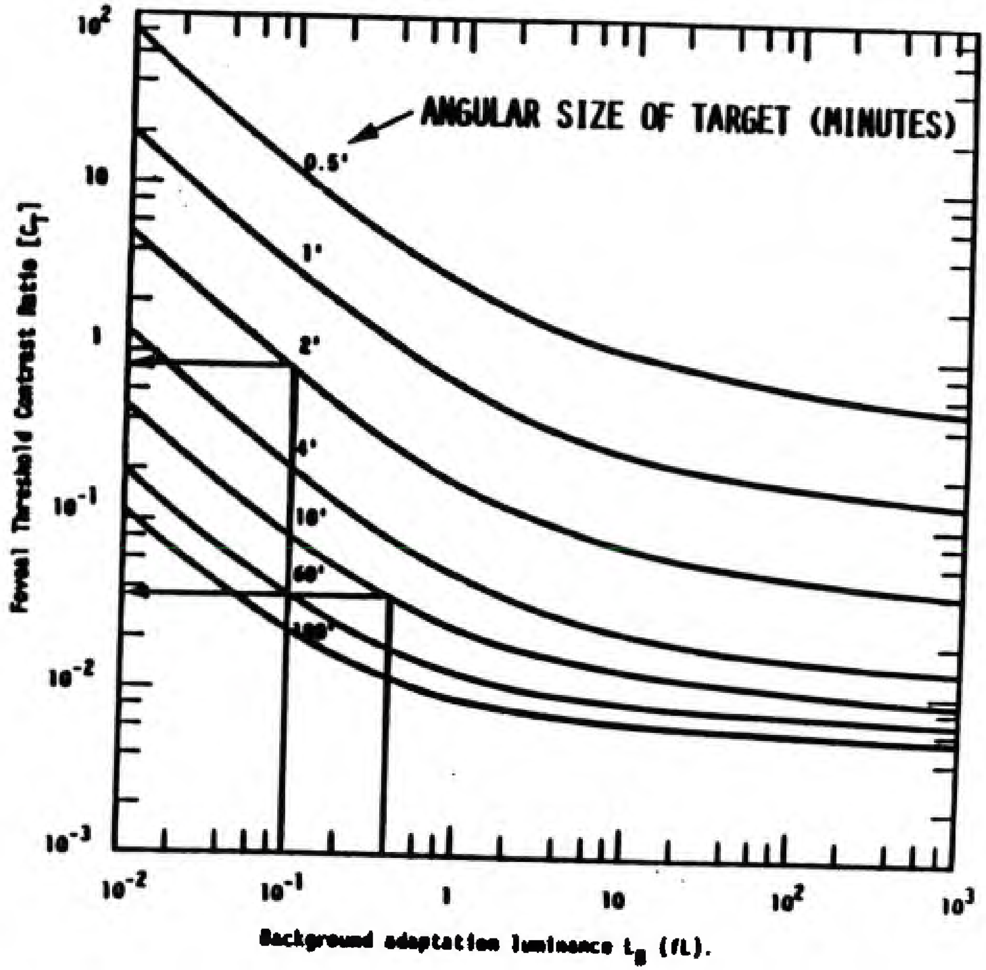


Figure 2.10. Target angular size.

0.05), the contrast ratio is 3 or greater. Against a good white surface (albedo 0.8), the contrast ratio is only 0.75.

The contrast ratio at the target (intruder) depends not only upon the albedos of the target and background but also upon the orientation of surfaces relative to the incident light. For instance, if the illumination is from a low angle (such as 30 degrees), the incident irradiance on a vertical surface may exceed twice that on a horizontal surface. Thus, even if all albedos are the same, the luminance of a portion of an intruder which is a vertical surface will be twice that of the horizontal ground surface and there will be a contrast ratio of 2.

Contrast, as seen by an observer, is determined by the contrast at the target, possibly modified along the sight path. Haze, rain, or other objects can remove light from the observed scene (which does not alter contrast) and add scattered or reflected light (glare) in the foreground. The latter always reduces contrast. Causes of contrast reduction can be scattering of the site lighting by haze, rain, snow, smoke, windows, guard glasses, etc. These latter causes, called veiling luminance, are particularly important if the luminaries result in glare toward the observer.

2.3.4 Positive Contrast

When contrast is positive the luminance of the target is greater than that of the background. Positive contrast is the objective of current lighting systems. Since the albedo (reflectance) of the target in the direction of the observer cannot be controlled by design of the surveillance system, the albedo of the background must be reduced to increase contrast. In the limit of very small background luminance, visibility is directly proportional to contrast.

There are several advantages to positive contrast. It is apparent that there is no upper limit to the value for C. Should the intruder be so cooperative or inept as to provide a highly reflective target, the contrast, and consequently the visibility, of the target would be very high. Even without high levels of luminance, experiments have shown that a light target on a dark background is more visible than a dark target on a light background. Lastly, the level of illuminance used for positive contrast detection makes it possible to distinguish between portions of the target. When contrast is positive, it is more likely that irregularities of the target can be seen, thereby providing information for assessment than when contrast is negative.

Illuminance, light energy per unit surface area, is proportional to the cosine of the angle between the normal to the surface and the direction of arrival of the light energy. Lights mounted near the ground serve to enhance positive contrast. Illuminance on vertical surfaces will then be much greater than that on horizontal surfaces. For example, the illuminance falling on a vertical surface from a light source one meter above the ground and 100 meters distant will be 100 times the illuminance on the ground below the target. The ratio decreases at greater distances.

The background can be darkened by reducing the surface albedo (black asphalt, black concrete, neoprene reservoir cloth, black polyethylene, etc.) or reducing the grazing angle of illumination. If the luminaires are placed low as illustrated in Figure 2.11, the illumination of the surface is proportional to sin θ. With 100 foot

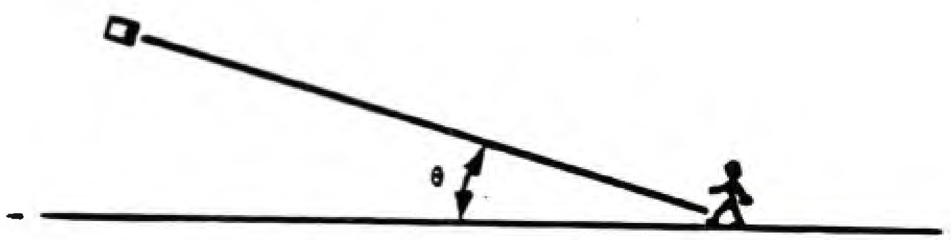


Figure 2.11. Illumination geometry .

poles, θ is of the order of 16° point halfway between poles or between piers. If the luminaires were lowered to half height the surface brightness would drop to about half the current value while the illumination of any vertical surfaces of an intruder would increase slightly. The incidence angle could be reduced even further by the use of a spotlight co-located with the observer.

Assessment data about the target shape is maximized by the broadside lighting. If the albedo of the target is relatively uniform, the angle between a surface on the target and the illumination can be estimated by the relative luminance. The surface toward the lights is bright, the surface facing away is in the shadow and dark, and intermediate regions are dim. For a three-dimensional, curved target,there is an inherent contrast across the target itself, and an observer can get an impression of the three-dimensional nature of the target.

To penetrate such a system the intruder should reduce his albedo to reduce contrast. If the intruder is good at this, the defense cannot ensure obtaining positive contrast. Thus, this concept is not defense enforceable.

Unfortunately, positive contrast concepts lead to a requirement for increased lighting illuminance. The standard visibility curve can be approximated, as shown in Figure 2.9, by a constant contrast line at high levels of background illumination (a region not pertinent to the positive contrast concepts) and by a constant target luminance at small background luminance. This latter line is the sloping line for which the product of the contrast ratio and the background is constant. For the VL curve, the target must have at least 0.4 foot Lamberts (fL, and for the VL curve, 0.05 fL luminance. The curves are based upon a 4 minute diameter target. This corresponds to a one foot diameter target at 800 feet. A prone intruder will represent a target of this size or perhaps a factor of two greater. Thus, for intruder detection, a luminance ranging from 0.2 to 0.4 fL is necessary for a high probability of detection of a stationary, light colored target and a factor of 8 less for a lower detection probability of a moving target.

If positive contrast concept is implemented the smart intruders would wear black. If we assume a reasonable value of 0.05 for the intruder albedo, the illuminance of the intruder would have to be 4 to 8 footcandles (fc) to assure a high detection probability. The current IES specification of 0.2 fc on a horizontal surface implies an illuminance of about 0.4 fc on a nearly vertical surface.

2.3.5 Negative Contrast

Negative contrast lighting concepts are defense enforceable. That is, attempts to counter the systems may counter part of the potential gain but cannot negate it. And, in the limit of elements with optical gain (to be treated in the next section), optimum intruder tactics cannot counter system gain. The concept is to have a background with an albedo of one (or greater) and, if possible, to raise the angle of incidence of illumination. For the intruder to try to match the background requires him to dress in white. Thus, for a given illuminance, the background and target luminance are large so that task achievement is enhanced.

The lighting system can be configured to produce a dark shadow on the surface. To be useful, this must point in a direction generally toward the observer. If it is not toward the observer it will appear as a very narrow dark line. A shadow, 0.6 m wide on the surface, going across the observer's field of view, 250 m from a guard will have the same angular subtense as a one-inch vertical surface. Thus, at 800 feet it will have an angular subtense of 10^{-4} radians, less than the resolution of the eye at the light levels of concern.

Maximum target shape data will be provided if broadside illumination is used because target shape will provide highlights, shadows and a range of shading, and because the target must be light colored to match the background, the range of luminance will be maximized.

What is the optimum penetration tactic? It probably depends upon the width of the treated ground cover, the characteristics of the untreated ground, and the alertness of the observer. One tactic (referred to as dash and wait) would be to dash across the bright background, hoping that the observer would not see or assess the cause of the dark spot and then stay motionless for a time trying to match the characteristics of a less bright region. The intruder would hope the guard would soon lose interest if he could no longer see anything. To counter this tactic may require the inclusion of some delay barrier in the bright field.

The alternate penetration tactic would be to try to match the background and minimize target contours. An example would be to use a white poncho to produce a low, shallow, sloping tent like structure over the intruder. The intruder would look something like a kite flat on the ground.

2.3.6 Negative Contrast with Optical Gain

Concepts using optical gain use a ground cover that scatters more light toward the observer than a white Lambertian surface. To try to blend into this background would be very difficult because the intruder cover would have to be matched to the background and some angular orientation may have to be maintained. Such concepts have the great advantage that the background luminance in a particular direction can be increased without increasing the illuminance and lamp power consumption. Thus, they should result in improved detection and discrimination, increased task achievement, without attendant increased power cost.

Examples of lighting concepts using optical gain are:

1. Silhouette lighting that uses nearly equal angles of incidence and reflection on a "glossy" surface (such as exists now off the water surface).
2. A co-located luminaire and observer with retro-reflecting beaded or corner reflector surface.

3. Broadside UV illumination with a fluorescent surface.
4. A co-located UV spotlight and a groundcover field of retroconverter UV-fluorescing devices.

One of the advantages of some of these concepts is that they use well developed technology from other fields such as highway and automobile lighting–beading of painted surfaces, discrete high gain corner reflector tape, automobile headlamps, etc. Another advantage is a reduced offsite visible signature. The gain makes the background bright only in directions toward the observers; to see this requires observation from behind the observer (i.e., airborne).

An array of small mirrors could provide high gain in a bistatic mode using broadside lighting but special alignment of individual elements would be needed to direct the reflected light toward the observer. Thus setup would be time consuming and the system could be degraded in time by the reflectors being knocked out of alignment.

These concepts will provide little three-dimensional assessment data concerning the target. While the target is silhouetted against the bright background, the contrast ratio of all parts of the target (high-lighted or shadowed) will be nearly unity. If there is adequate illumination in regions near the enhanced reflectance ground cover, added diagnostic features may be visible when the target reaches the untreated region following an assured detection in the bright zone.

For our special case of water surface between piers, we may presently observe the high optical gain negative contrast ambient conditions resulting from many small lights specularly reflecting off small wavelets if the observer is in the bay. The target will be silhouetted against the glint. Additionally, the surface will exhibit a residual signature caused by motion. This "wake" will be a significant assistance in detection.

2.4 LIGHTING SYSTEMS

This section discusses aspects of the lighting systems important to understanding it in relationship toa ssigment. This section is also extracted directly from Reference 1.

2.4.1 Wavelength

The color of light projected upon the surface of the water or pier is important. Figure 2.12 shows the relative output radiance of High Pressure Sodium (HPS) lamps and tungsten-iodide (headlight) incandescent lamps. Comparison with Figure 2.13 shows that HPS is matched to the human eye (both photopic and scotopic) vision quite well, while poorly matched to the Silicon Vidicon CCTV spectrum. The CCTV spectrum is much more closely matched to the tungsten-iodide headlight spectrum which is roughly a 3200° blackbody radiator.

Table 2.2 provides general comparison of the characteristics of lamps for steady operation visible light output. Lamps of the general types given are manufactured with a much wider range of each of the characteristics listed; however, lights for security surveillance systems will probably fall in the ranges given. Most standard perimeter lighting systems use lamps in the 150 W to 400 W range except for incandescent backup systems that typically use 1000 to 1500 W.

The efficacy of the various visible light sources given in Table 2.3 is a measure of the relative response of the eye to a watt of lamp power when the eye is adapted to relatively high illumination levels (photopic adaptation). In other words, for a constant effective illumination under these conditions the lamp power must be inversely proportional to the efficacy.

An examination of the data in the table shows that the incandescent lamp is inefficient for photopic excitation (it radiates energy over too wide a wavelength band) and the low pressure sodium is most effective (it radiates most of its power in two lines near the peak of the photopic curve). For a night adapted eye (scotopic vision), the effectiveness of the low pressure sodium drops radically and the effectiveness of the non-sodium lamps increases relative to HPS primarily because the HPS, being deficient in blues and greens, is less effective for stimulating photopic response. Thus, if the average scene brightness is low enough that eyes become well dark adapted, the effectiveness advantage of the sodium lamps disappears. If the lighting is to be used primarily for use with silicon vidicons, the effectiveness of incandescent lighting is comparable to that of the sodium vapor lamps and the effectiveness of mercury arcs is low.

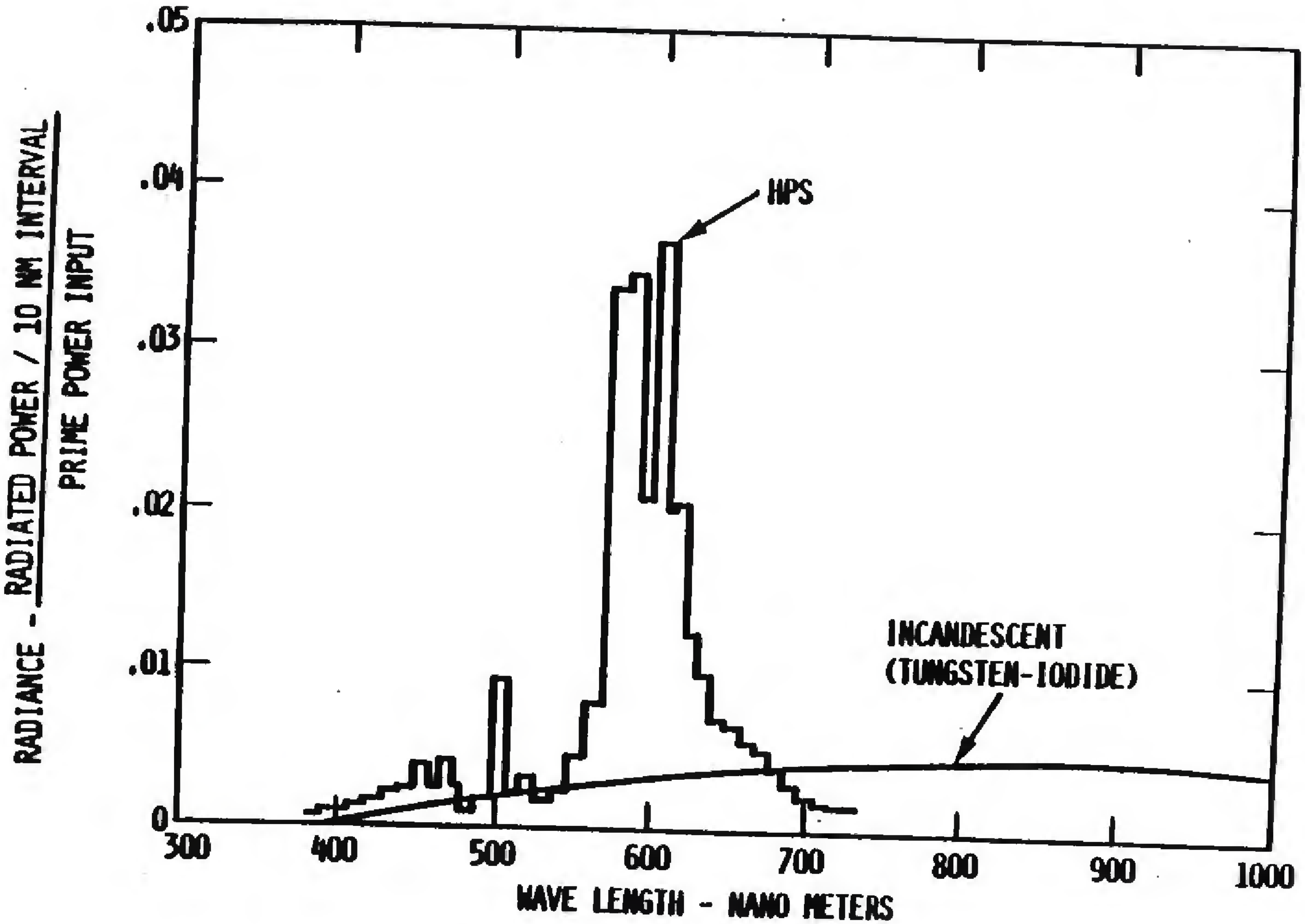


Figure 2.12. Luminaire spectrum.

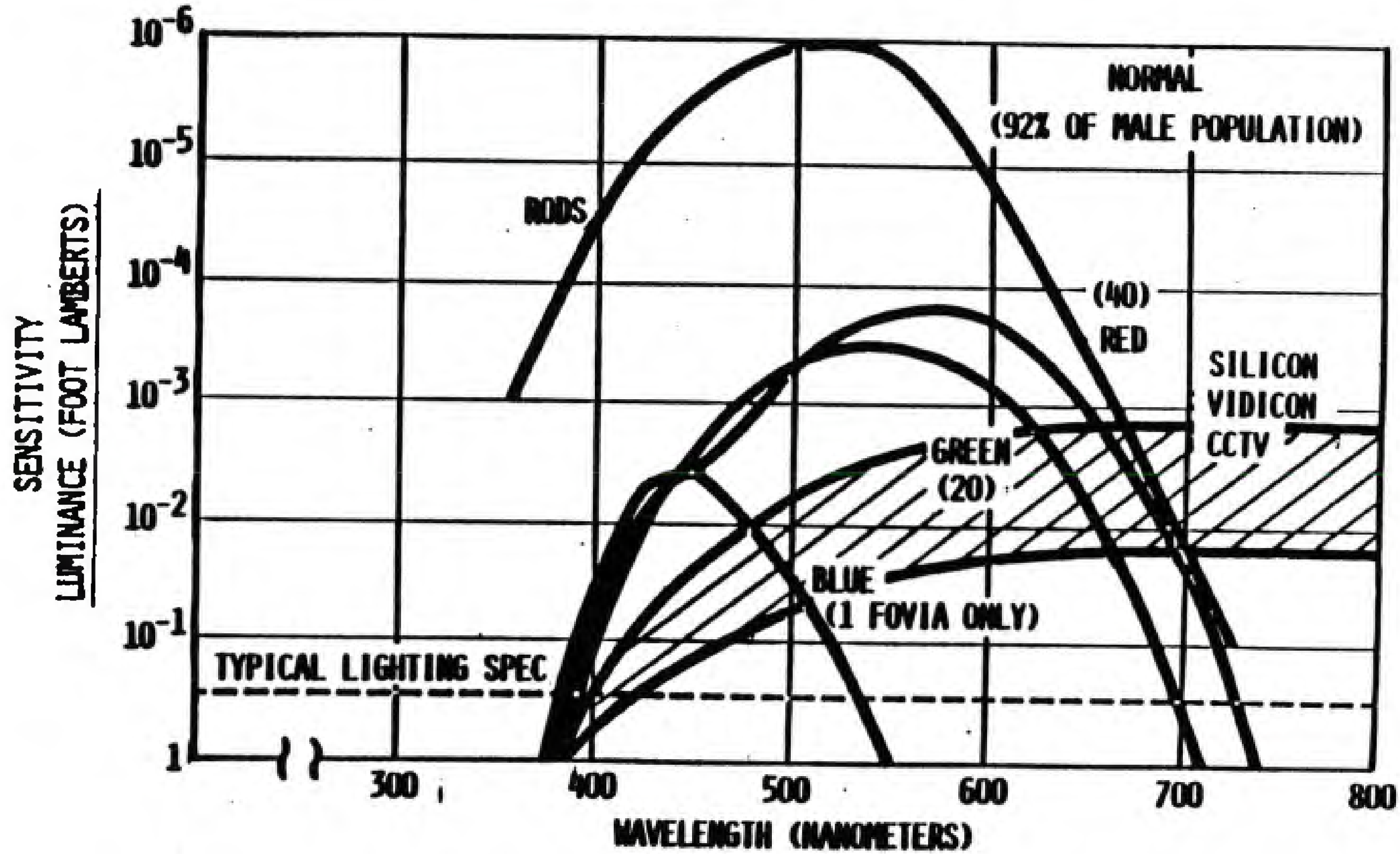


Figure 2.13. Spectral Sensitivity.

Table 2.2. Characteristics of typical lights for security surveillance.

Lamp Type	Input Power (watts)	Life (hours)	Efficacy (Lumens/w lamp only)	Color[1] Rendition
High Pressure Sodium	100-1000	10,000-20,000	100-140	F
Mercury, Clear	100-1000	16,000-24,000	40-60	VP-P
Mercury, Deluxe White	100-1000	16,000-24,000	45-63	P-F
Meal Halide	400-1000	10,000-15,000	80-100	G-VG
Low Pressure Sodium	90-180	18,000	150-180	P
Florescent	40-220	9000-30,000	55-88	G-E
Incandescent (Tungsten Iodide)	35-1500	250-2000	15-25	VG-E

[1] E - Excellent, VG - Very good, G - Good,
F - Fair, P - Poor, VP - Very Poor

Table 2.3. Relative effectiveness of various light sources.

		Task		
	Electrical Efficiency	Eye Photopic	Eye Scotopic	Si Vidicon
High Pressure Sodium	0.84	1.00	1.00	1.00
Mercury Clear	0.91	.46	.90	.28
Mercury Deluxe White	0.91	.48	.73	.42
Metal Halide	0.87	.70	.64	1.39
Low Pressure Sodium	0.83	1.40	.48	1.06
Fluorescent (Cool White)	0.9	.64	1.35	.56
Incandescent	1.0	.19	.44	.91

2.4.2 Luminaires

Luminaires as used here are the fixtures for holding the actual lamps. In general these luminaires have a reflective surface behind the lamp to redirect light shining in the wrong direction and they may have a refractive element in front for additional control of the light distribution in the beam. The exact illumination pattern produced depends upon the luminaire construction, the lamp type and the placement of the bulb in the luminaire.

The collimating element in spotlights is usually a reflector if a high efficiency is needed. (Efficiency meaning the fraction of the emitted light that is in the beam.) This is also referred to as optical control. A high degree of optical control requires a small mission source size. Thus, in the order of desirability for spotlight applications are tungsten halide incandescent, multivapor HID, and mercury HID lamps. Tungsten Halide spotlights are readily available using bulbs developed for automobile trade. These are typically 35 to 55 watt, 12 VDC bulbs. The beam pattern (isocandela curves) of the General Electric PAR 36 37.5 W Spotlight are shown in Figure 2.14.

Spotlights are also made for HID lamps. These are categorized as NEMA-1 if they have beam spreads of 10° to 18° . Beam spread is defined as the full width of the beam to the point the luminous intensity is 10 percent of the maximum. The angular patterns and for a Lucalox lamp are shown in Figure 2.15. The metal halide provides a greater on-axis light concentration because its emitting volume is smaller. One would expect the pattern using a mercury lamp would be intermediate (if the socket is adjusted to place the light center length of the lamp at the spotlight focal point). If the light were radiated isotopically, the intensity would be about 80 cp per 1000 lumens. Thus, the spotlight increases the intensity by factors of 300 to 400, and the illumination at 300 would be the same as the lamp without a luminaire would produce at 15 to 30m. Table 2.4 provides the beam widths of spotlight luminaires.

Table 2.4. Spotlight beam characteristics..

	Super Oscar	GE-PAR36	Nema 1 ×1	
			Metal Halide 400 W	Lucalox 400 W
Beamwidth 50% Max.	1.6 × 2.1	2.0 × 4.9	4.3 × 4.6	4.0 × 3.7
25% Max.	2.7 ×3.1	3.0 ×6.3	7.5 ×8.0	6.5 ×6.5
10% Max.	4.1 ×4.7	4.2 ×7.5	13 ×14	12.5 ×12
Specific Beam Intensity cp/w		2000	2700	3250

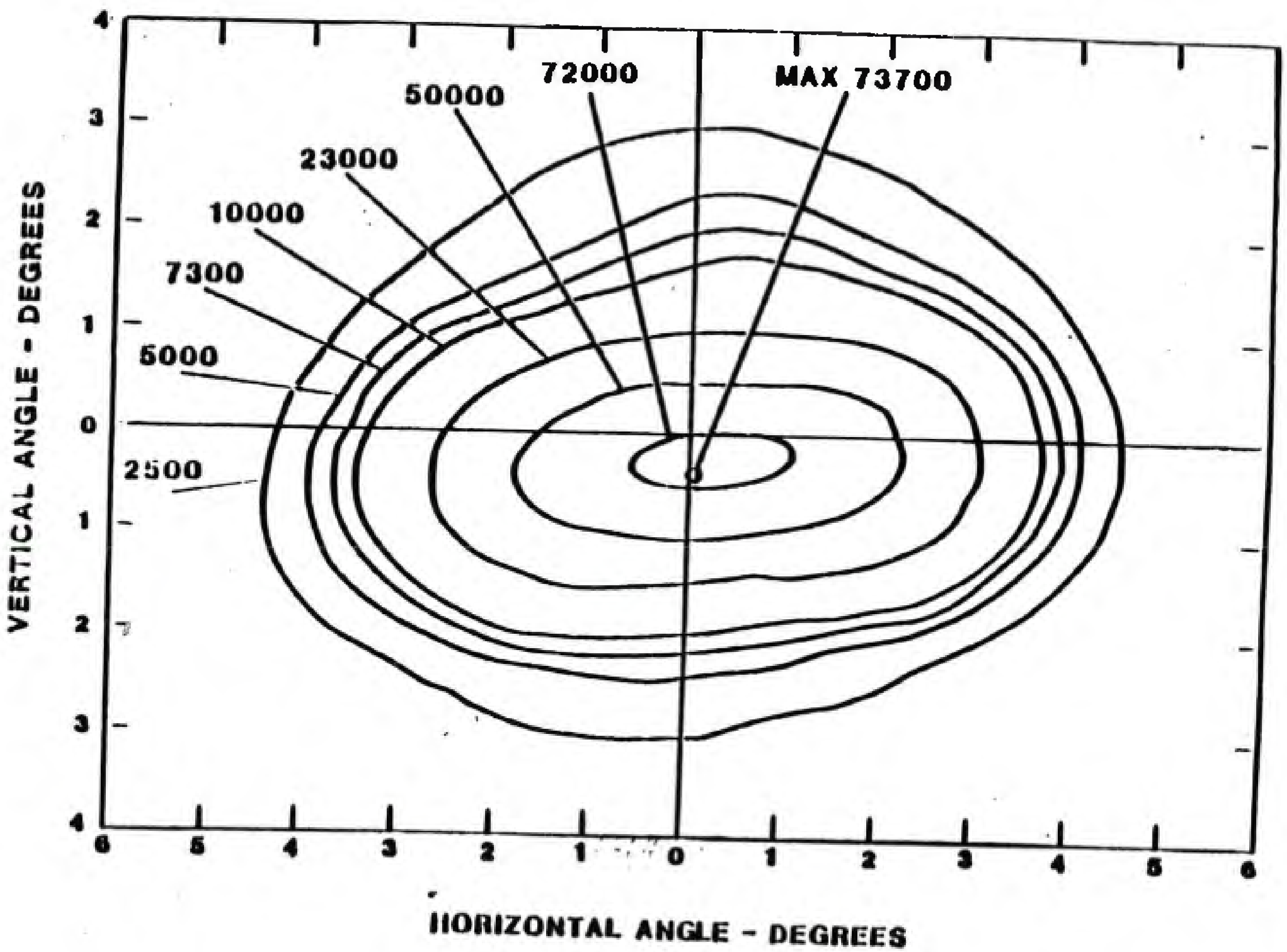


Figure 2.14. **Measured isocandela contours for GE H7616 lamp.**

PHOTOMETRIC DATA
PER 1000 LAMP LUMENS

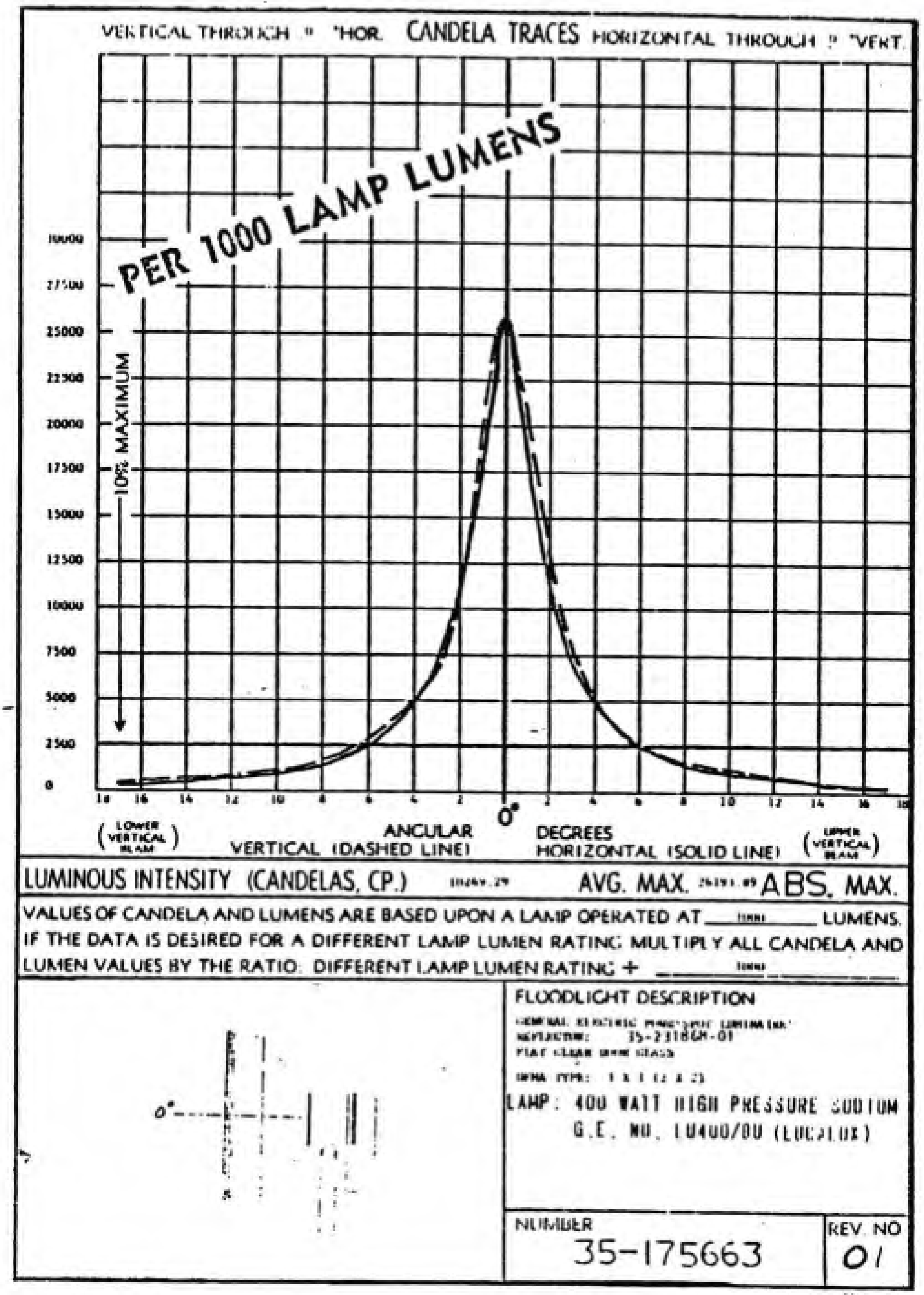


Figure 2.15. Photometric data for a high pressure sodium lamp in a Power-Spot reflector.

2.4.3 Restrike Delays

The arc discharge lamps require the lamp to heat the discharge material to vaporize before the full brightness is achieved. This results in a warmup delay. Moreover, if the power is interrupted momentarily so that the vapor deionizes, the lamp impedance becomes so great that the arc will not restrike. The amount of cooling and hence pressure reduction needed before restrike depends upon the normal operating pressure and the no load voltage produced by the lamp ballast. Thus, the low pressure sodium lamps require little or no cooling and the high pressure sodium lamps quickly restrike because the ballast produces a high voltage starting pulse. Warm up and restarting delays are given in Table 2.5. Mercury arc and fluorescent light ultraviolet sources experience the same delays as do their visible light counterparts.

Table 2.5. Warm up and restart delays.

	Warm Up Time[1] (minutes)	Restart Delay
High Pressure Sodium	3 to 4	05. to 1.5
Mercury	5 to 7	3 to 6
Metal Halide	3 to 5	10 to 15
Low Pressure Sodium	7 to 15	0 to 0.5
Fluorescent	seconds	0
Incandescent	0	0
Xenon Flash	0	0

[1]Time to reach 80 percent of ultimate output.

Restrike delays would figure most heavily in selecting lamps for dynamic deterrent lighting systems or if glare caused turning lights off during docking.

2.5 CCTV

This section provides a tutorial on CCTV suitable for understanding how such systems may aid security. This is extracted directly from "Intrusion Dection Systems Handbook," Vol II, by Sandia National Laboratories.

2.5.1 Cameras and Displays

Closed circuit television (CCTV) is slowly augmenting and supplanting direct visual detection and assessment. Currently, it is used to acquire and display visual data to be evaluated by security personnel. Current implementation is limited to black and white representations using a silicon diode array vidicon. The silicon vidicon is used because of reliability, sensitivity, lack of image burn-in and good antiblocking characteristics. The spectral response of such a camera tube compared with a low light level tube in Figure 2.16.

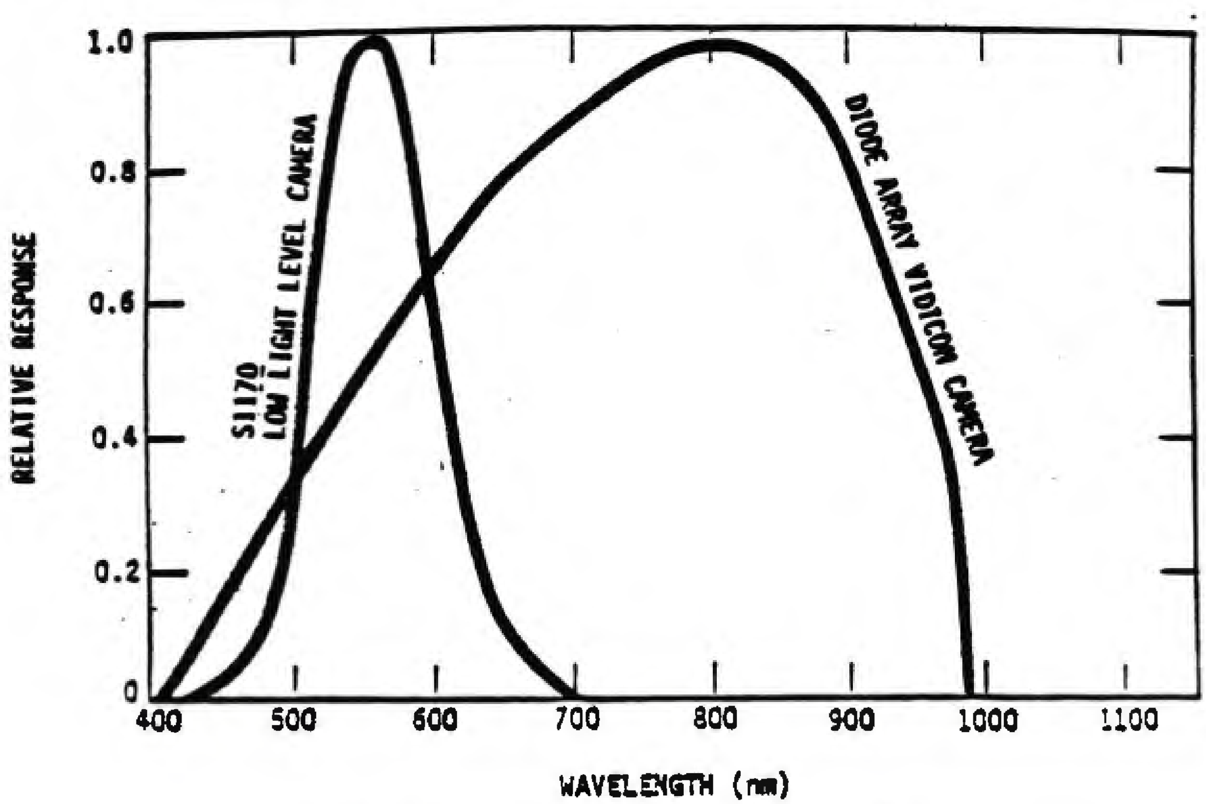


Figure 2.16. Spectral response curves.

Note that the lowlight level CCTV (LLLCCTV) is better matched in spectral sensitivity to the HPS lamps and the human eye.

Standard American television specifications are 262-1/2 lines per field (525 per frame). The balance of this subsection is taken from Reference 8, "The Intrusion Detection Systems Handbook."

Because the electron beam must be disabled (blanked) during the retrace interval from the right to the left side of the target (after each field), about 8% of 525 lines in each frame are lost, leaving approximately 485 lines in each frame that are actively used to convert the optical image on the photoconductive layer into a video signal.

The above discussion describes scanning functions in terms of the U. S. standard. Since commercial U. S. power is furnished at a 60 Hz rate, 60 Hz became the field rate for video systems in the U. S. In the C.C.I.R. (West-European) system, a 50 Hz power frequency and a 625 line/frame scan rate are used. (With the field rate chosen to coincide with the power frequency, any small amount of hum (ripple) due to imperfect power supply filtering would remain stationary on the viewing screen, thus minimizing any obtrusive distractions.) Many manufacturers supply both the U. S. (60 Hz, 525 line) and C.C.I.R. (50 Hz, 625 line) systems as options.

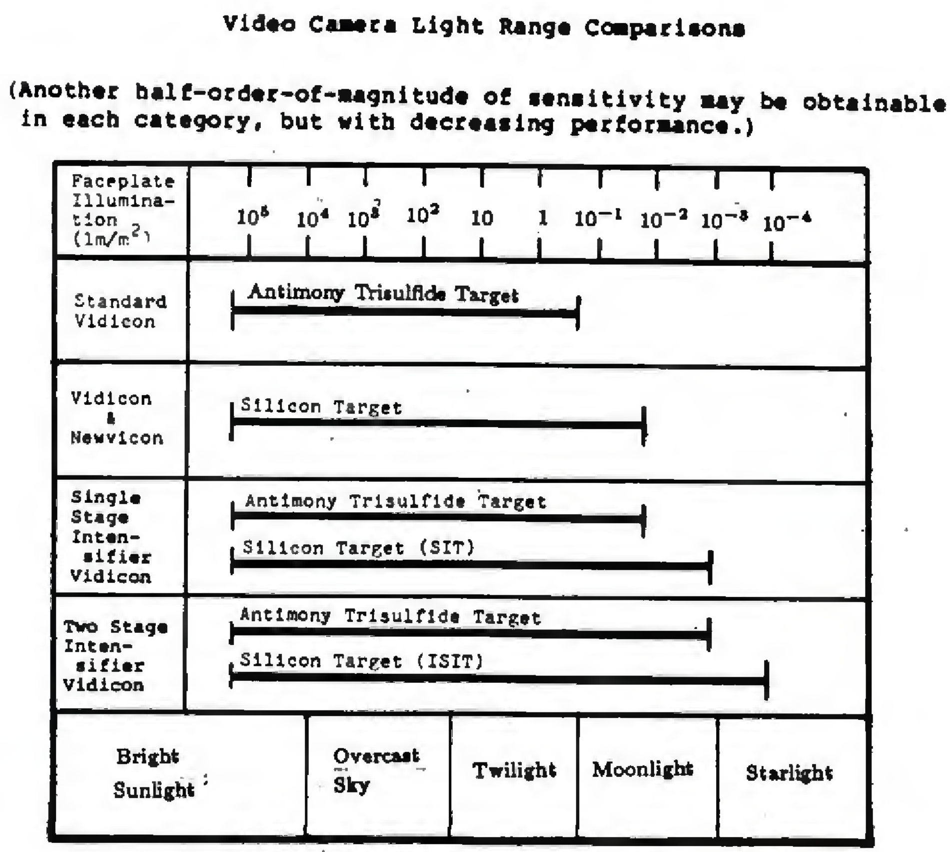
The amount of light energy necessary to produce a usable video output signal from a given camera is a function of (a) the type and brightness of the source, (b) the amount of source light energy actually falling upon (illuminating) the scene to be televised, (c) the percentage of this light energy which is reflected from the scene, (d) the fraction of this energy which passes through the lens and subsequently illuminates the image tube target (faceplate illumination), as well as (e) the relative sensitivity of the particular image tube in use.

Cameras may be subdivided into several classes, determined by their relative sensitivities and spectral response as illustrated in Table 2.6. Several of the more common classes are discussed below.

The basic function of the lens in a video camera system is to focus the light energy reflected off the object (entering the lens) onto the image tube target where it is then converted into an electronic video signal. Aperture, focal length, and associated field-of-view are important lens parameters.

The relative aperture, f/number (f/no.), or speed of a lens system is a measure of its light gathering ability and indirectly expresses the maximum diameter of the lens system. The f/number of a lens is simply the ratio of the focal length (f) to

Table 2.6. Video Camera Light Range Comparisons.



the clear aperture. As an example, an f/2 lens has an aperture diameter of one-half its focal length, so that an f/2 lens with a focal length of 100 mm (4")would have an associated aperture diameter of 50 mm (2"). Note that the clear aperture of the lens is not simply the physical outer lens diameter but the diameter of the iris image as seen when looking into the front of the lens (the iris, controls the physical diameter of the clear aperture). (It should be noted that although verbal pronunciation is "f-number," this still refers to the ratio of focal length to clear aperture and is written f/number.)

The f/number of a lens is of great importance in determining the amount of image tube faceplate illumination attainable with a given scene brightness. Faceplate illumination is directly proportional to the clear aperture area, which in turn varies with the square of the aperture diameter. That is,

$$\left[\frac{I_1}{I_2} = \frac{(f/no)_2}{f/no)_1}\right]^2$$

This means that halving the lens f/number (for example, from f/4 to f/2) will quadruple the faceplate illumination for the same scene brightness. For this reason, standardized f/numbers vary in multiples of $\sqrt{2}$ (such as f/1, f/1.4, f/2, f/2.8, f/4, etc.) so that the resultant illumination level either doubles or is halved between adjacent-stops.

The focal length of a lens (f) describes its relative magnification (the ratio of image size to object size at a given object distance), as well as determining the image location. The magnification of a given lens may be expressed relative to a reference 25 mm(1") focal length lens. A 100 mm (4") lens would have four times the magnification of a 25 mm lens, or 4:1. Similarly, a 12.5 mm (1/2") lens would have a magnification of 0.5:1, half that of a 25 mm lens.

The distance between the nearest and most distant objects (along the optical axis) which are in acceptable focus is the lens depth of field. Depth of field increases with decreasing aperture (larger/ number) and for any given aperture is largely dependent on the design quality of the lens. the hyper focal distance is the distance at which the lens must be focused such that the depth of field extends to infinity. Hyperfocal distance increases with aperture and focus quality.

2.5.2 Planning CCTV Applications

The object size which can be imaged in a video scene is determined by the lens field-of-view (FOV). This is a function of lens focal length (f) and image size (camera image tube target of width W_T and height H_T. The resulting field-of-view will have a particular width and height (H_F) at a specific field distance (D_F) as follows:

$$Horizontal\ \ FOV = W_F = W_T\left(\frac{D_F}{f} - 1\right)$$

$$Vertical\ \ FOV = H_F = H_T\left(\frac{D_F}{f} - 1\right)$$

If it is assumed that D_F is much larger than f, the field-of-view can be expressed as a solid angle with horizontal component θ_H and vertical component θ_V as follows:

$$\theta_H = 2 \ tan^{-1} \frac{W_T}{2f}$$

$$\theta_V = 2 \ tan^{-1} \frac{H_T}{2f}$$

The usable image size (W_T and H_T) is determined by the size of the camera tube target. Table 2.7 below lists the dimensions for the standard 1" and 2/3" (16 and 11 mm diagonal) "C" mount formats. Note that 16 mm or 11 mm (diagonal)

Table 2.7. Image Tube Format.

FORMAT	Target Width (W_T) in (mm)	Target Height (H_T) in (mm)
1 in (16mm)	1/2 (12.7)	3/8 (9.525)
2/3 (11 mm)	1/3 (8.47)	1/4 (6.35)

does not convert directly to the 1 inch or 2/3 inch formats listed. Only a portion of total faceplate area on a 1 inch format image tube is used for scanning purposes. This area, referred to as the image tube target is typically 1/2 inchwide (W_T) by 3/8 inch high (H_T) on a 1 inch format image tube. The imaginary circle containing this 1/2 x 3/8 inch rectangle is $[(1/2)^2 + (3/8)^2]^{1/2} = 0.63$ inch or approximately 16 mm in diameter. The same idea applies to a 2/3 inch format.

Using the value for a 1-inch format lens, angular field-of-view, horizontal FOV, and vertical FOV can be calculated for various standard lenses as illustrated in Table 2.8, Figure 2.17, and Table 2.9.

<u>Practical FOV Considerations</u> – In many cases, the camera will be mounted on a pole or tower some distance above the ground (at height H_C) and tilted down (at angle θ_T) towards the scene to be televised.

in this case the tilted field-of-view is given as:

$$H_f = H_C \frac{1}{tan\left(\theta_T + \frac{\theta_V}{2}\right)} - \frac{1}{tan\left(\theta_T + \frac{\theta_V}{2}\right)} = H_C \ K_1$$

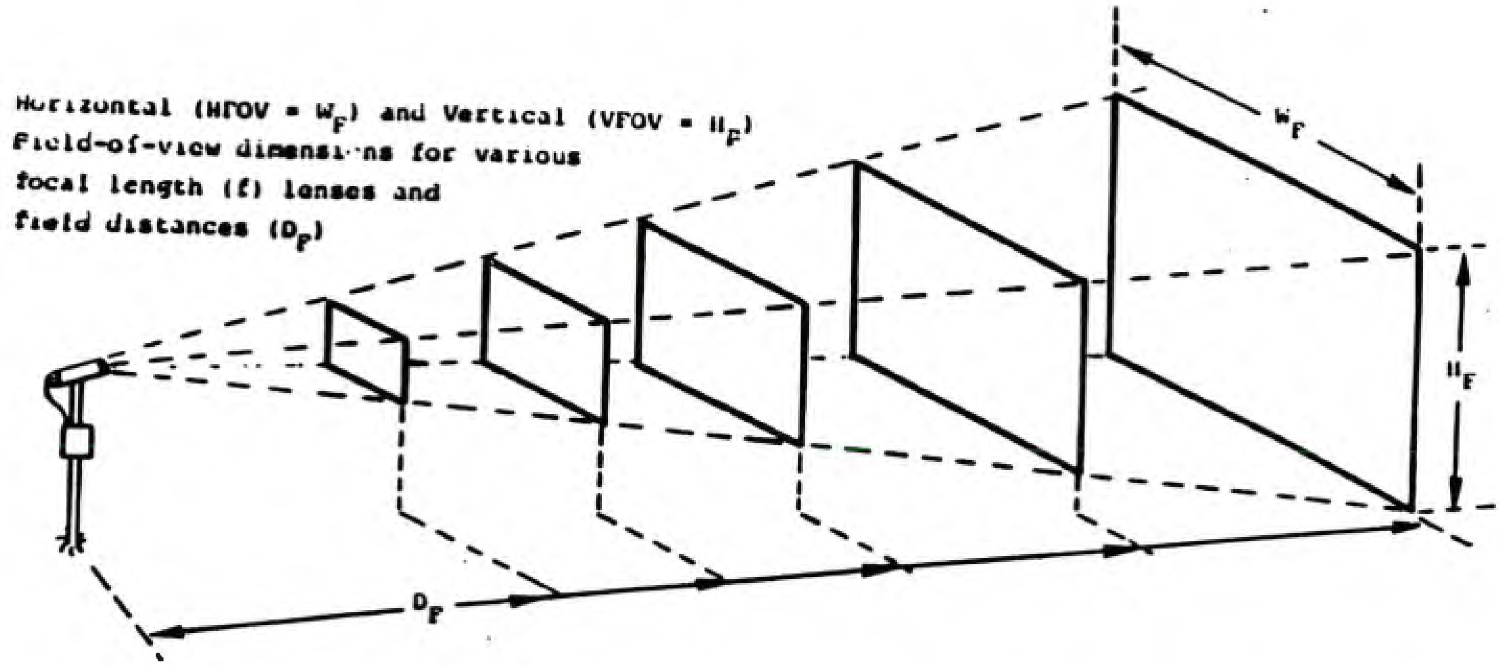


Figure 2.17. Horizontal (W_F) and Vertical (H_F) Field-of-View Dimensions.

Table 2.8. Angular Field-of-View.

Angualr Field-of-View
(assumes 1-inch format lens)

f (mm)	θV (degrees)	θH (degrees)
12.5	41.71	53.86
25	21.57	28.50
50	10.88	14.48
75	7.27	9.68
100	5.45	7.27
150	3.64	4.85
300	1.82	2.43

$$\left(true\ \ of\ \ \theta_T > \frac{\theta_V}{2}\right)$$

and the blind zone between the base of the camera tower and the nearest visible point in the televised scene is:

$$D_B \frac{H_C}{tan\left(\theta_T + \frac{\theta_V}{2}\right)} = H_C K_1$$

As illustrated in Figure 2.18, Table 2.10 lists specific values for coefficients (K_1, K_2) which allows direct computation of H_F and D_B for common values of f and θ (1 inch format).

If the maximum field width for adequate resolution (W_R) is known and a choice of lens and camera mounting height (H_C) has been made, the field distance (D_R) can be calculated as:

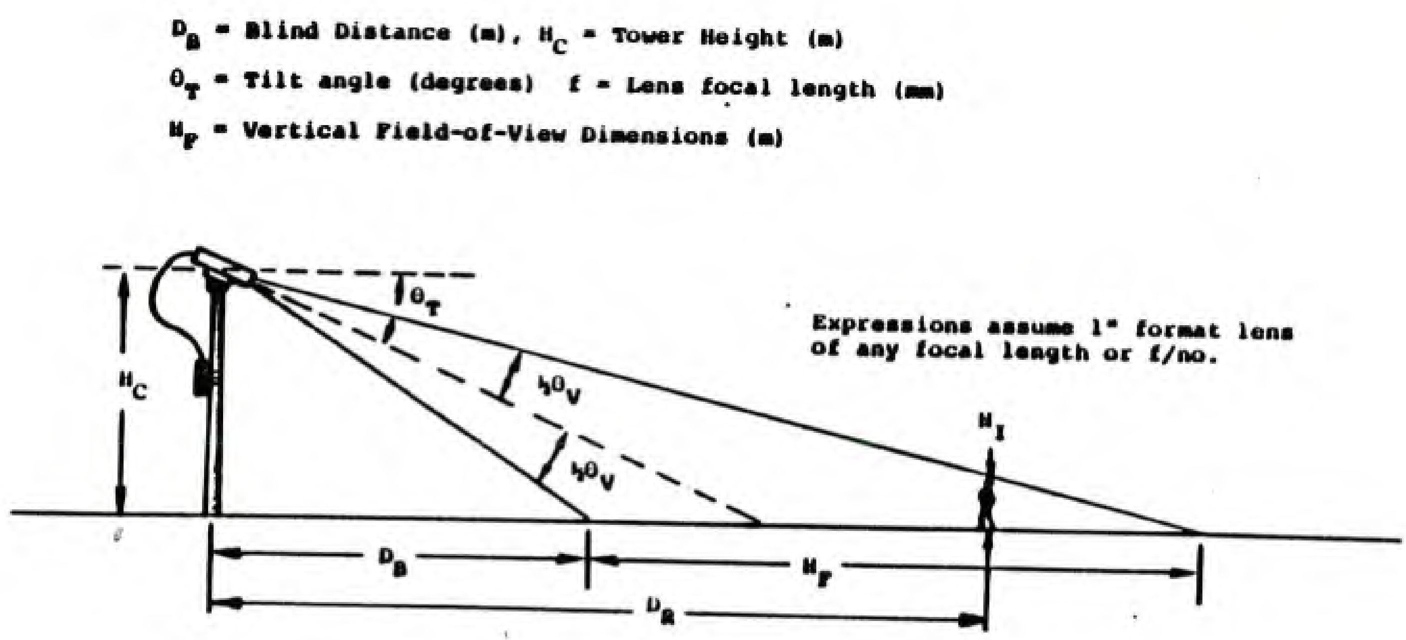


Figure 2.18. Blind Distance and Vertical Field-of-View.

Table 2.9. Field-of-View Dimensions.

(assumes 1-inch format lens)

Dark line through
table indicates 0.75%
resolution threshold

D_F(m)	5		10		15		25		50		75		100		150		300	
f(mm)	H_F	W_F	H_F	W_F	H_F	W_F	H_F	W_F	H_F	W_F	H_F	W_F	H_F	W_F	H_F	W_F	H_F	W_F
12.5mm	3.81	5.08	7.62	10.1	11.4	15.2	19.0	25.4	38.1	50.8	57.2	76.2	76.2	101.	114.	152.	228.	104.
25mm	1.9	2.5	3.0	5.1	5.7	7.6	9.5	12.7	19.1	25.4	28.6	38.1	38.1	50.8	57.2	76.2	114.	152.
50mm	1.0	1.3	1.9	2.5	2.9	3.8	4.8	6.4	9.5	12.7	14.3	19.1	19.1	25.4	28.6	38.1	57.2	76.2
75mm	0.6	0.8	1.3	1.7	1.9	2.5	3.2	4.2	6.4	8.5	9.5	12.7	12.7	16.9	19.1	25.4	38.1	50.8
100mm	9.5	0.6	1.0	1.3	1.4	1.9	2.4	3.2	4.8	6.4	7.1	9.5	9.5	12.7	14.3	19.1	28.6	38.1
150mm	0.3	0.4	0.6	0.8	1.0	1.3	1.6	2.1	3.2	4.2	4.8	6.4	6.4	8.5	9.5	12.7	19.1	25.4
300mm	0.1	0.2	0.1	0.4	0.5	0.6	0.8	1.0	1.6	2.1	2.4	3.2	3.2	4.2	4.8	6.3	9.5	12.7

$$D_R = \frac{W_R}{2\, tan \frac{\theta_R}{2}}$$

(Note that D_R is the field distance D_F where W_F is equal to W_R).

It is normally desired to (at least) provide a complete image of an erect human form at a distance D_R from the camera (Figure 2.18), so for a camera mounting height of H_C and an intruder height of H_I, the required tilt angle is:

$$\theta_T = tan^{-1} \frac{H_C - H_I}{D_R} + \frac{\theta_V}{2}$$

2.5.3 Video Processing

Video recording and processing is beginning to have its affect on security. Recording is very functional since it can generate an "instant replay" capability. Video processing is very useful when used to produce an alarm and highlight the image changes that caused the alarm.

Table 2.10. Calculation Factors for Blind Distance and Vertical Field-of-View.

(Assumes 1" format lens)

Focal Length (mm)		Tilt Angle θ_T (degrees)												
		0.0°	1.0°	2.5°	5.0°	7.5°	10°	15°	20°	25°	30°	35°	40°	45°
12.5	K_1	2.6	2.5	2.3	2.1	1.9	1.7	1.4	1.2	1.0	0.8	0.7	0.6	0.4
	K_2									12.8	5.4	3.3	2.3	1.8
25	K_1	4.0	4.8	4.2	3.5	3.0	2.6	2.1	1.7	1.4	1.2	1.0	0.8	0.7
	K_2							11.5	4.5	2.6	1.7	1.2	1.0	0.8
50	K_1	10.5	8.9	7.2	5.4	4.4	3.6	2.7	2.1	1.7	1.4	1.2	1.0	0.8
	K_2					23.4	8.9	3.3	1.7	1.1	0.8	0.6	0.5	0.4
75	K_1	15.7	12.3	9.3	6.6	5.1	4.1	3.0	2.3	1.8	1.5	1.3	1.0	0.9
	K_2				35.4	9.7	4.8	2.0	1.1	0.7	0.5	0.4	0.31	0.26
100	K_1	21.0	15.[illegible]	10.9	7.4	5.5	4.4	3.1	2.4	1.9	1.6	1.3	1.1	0.9
	K_2				17.8	6.4	3.4	1.5	0.8	0.5	0.4	0.29	0.23	0.19
150	K_1	31.5	20.3	13.2	8.4	6.1	4.8	3.3	2.5	2.0	1.6	1.3	1.1	0.9
	K_2			71.0	9.6	4.0	2.2	1.0	0.6	0.4	0.25	0.19	0.15	0.13
300	K_1	63.0	30.0	16.8	9.7	6.8	5.2	3.5	2.6	2.1	1.7	1.4	1.2	1.0
	K_2		607	19.2	4.3	1.9	1.1	0.5	0.27	0.18	0.13	0.10	0.08	0.06

K_1 = Blind distance (D_B) coefficient

K_2 = Vertical Field-of-view (VFOV) coefficient

$D_B = H_C K_1$ (H_C, D_B same dimensions)

$H_F = H_C K_2$ (H_C, H_F same dimensions)

H_C = Camera Height (any dimensions)

VideoTek and Quantex, among others, produce videoprocessors with application to Naval Security.

In general, detection of motion within the field of view (FOV) is based on detection of changes of brightness or video signal level. This is accomplished by comparing scenes at different times by subtraction. Video signals from the two scenes are examined in discrete areas, or resolution cells, to increase sensitivity and to provide data concerning the location of moving object.

The digital motion detector whose characteristics are described here is manufactured by VideoTek. Detector/processors capable of operating with 4, 8, 12 or 16 camera inputs are available. For descriptive purposes a single camera channel will be described first.

The motion detection unit (MDU) accepts video in the standard 2:1 interlace, 525 line format. The video level from a horizontal scan line is sampled at 128 points. Every other horizontal line is scanned, providing 128 lines by 128 sample points per frame, providing a total of 16,384 sample points per FOV. The video level at each point is quantized in a 4-bit word, dividing the available gray scale into 16 levels. This array of 65,536 bits is stored in a static MOS memory and used as a reference frame. Corresponding fields of subsequent frames are compared with the reference frame, point by point, to detect changes of scene brightness in each resolution cell.

Nominally, a motion alarm is declared when the video level in a resolution cell changes two levels of the quantized samples (12.5 percent). Alarm data is stored in a separate storage register, storing the X and Y coordinates of the cell and a one-bit alarm flag. The flag is used to produce a flashing brightened cell on the video display to locate the alarm point. The flashing rate is 6 Hz with a duty cycle short enough that the scene is supposed to be visible through the flasher. However, the flasher has to obliterate the cell in every second or third frame. VideoTek says that it would be a simple modification to turn off the flasher manually to facilitate examination of the scene. This seems important for assessment purposes. As the moving object progresses through the FOV a series of flashing cells provides a track.

VideoTek's "Systems Theory of Operation" reports that "...independent test shows that when the motion detector is operating with a 95 percent probability of detection, the probability of detection for a human operator is less than 5 percent." This independent evaluation was performed at the Air National Guard site in Boise, Idaho.

The simplest multi-channel MDU (MDU-2) has options for maxima of 4, 8, 12, and 16 camera inputs. The camera channels are scanned sequentially, using a single 16,384 point memory.

The MDU has a front panel selectable, six step refresh rate. The refresh rate is the rate at which the reference frame is replaced. Refresh intervals of 1, 2, 4, 8, 16 or 32 fifteenths of a second are available. Since the memory is dedicated to a single camera at a given time, a new reference frame must be established each time a camera is selected. The dwell time per camera is the selected refresh interval. A long refresh interval is desirable to enhance probability of detection of slow-moving targets. For a single camera the rate should be only fast enough to accommodate changing light levels, such as those due to cloud shadows. However, for multiple cameras the refresh rate should be short enough to minimize the probability that an intruder can move through the FOV while the camera is idle. Time intervals are given in Figure 2.19. For example, if four cameras were time-sharing an MDU-2 with a refresh interval of 32/15 seconds, the table in Figure 2.19 shows each camera would be "on" for 2.1 seconds, then off for 6.3 seconds while the other three cameras are on.

The times shown in Figure 2.19 are extended if there is a detection in any zone. When the basic MDU detects an intrusion,the detector stops sequencing through the cameras for a predetermined length of time while the alarm map is added to the image (Spoofing presents a problem.)

A dual scan memory option is provided to avoid the difficulty described above. In this system two memories are used; one with a fixed 1/15 second, refresh interval and the second with a selectable interval from the set already presented. The cameras are switched each 1/15 second and the fast memory refreshed at each change as discussed above. The slower memory refreshes at intervals that are related to the number of cameras. That is, the reference frame must be held at least (N+1)/15 seconds, where N is the number of cameras, so that it can be compared with the next scene from the same camera. It appears that the processor must keep track of the channel number associated with the slow memory. While this scheme solves the problem of detecting fast moving targets, the slow memory is time-shared among cameras and if the number of cameras is large and the refresh rate low, a slow target may go undetected. VideoTek recommends a refresh rate of 8/15 second for the slow memory.

Still another option provides storage for an independent alarm map for each channel. As discussed below under controls, the operator can bring up the video on any channel. Having individual alarm maps, he can monitor the scene and the alarm map as he chooses.

Refresh Interval (sec)	Camera on Time (sec)
1/15	0.067
2/15	0.133
8/15	0.533
16/15	1.067
32/15	2.133

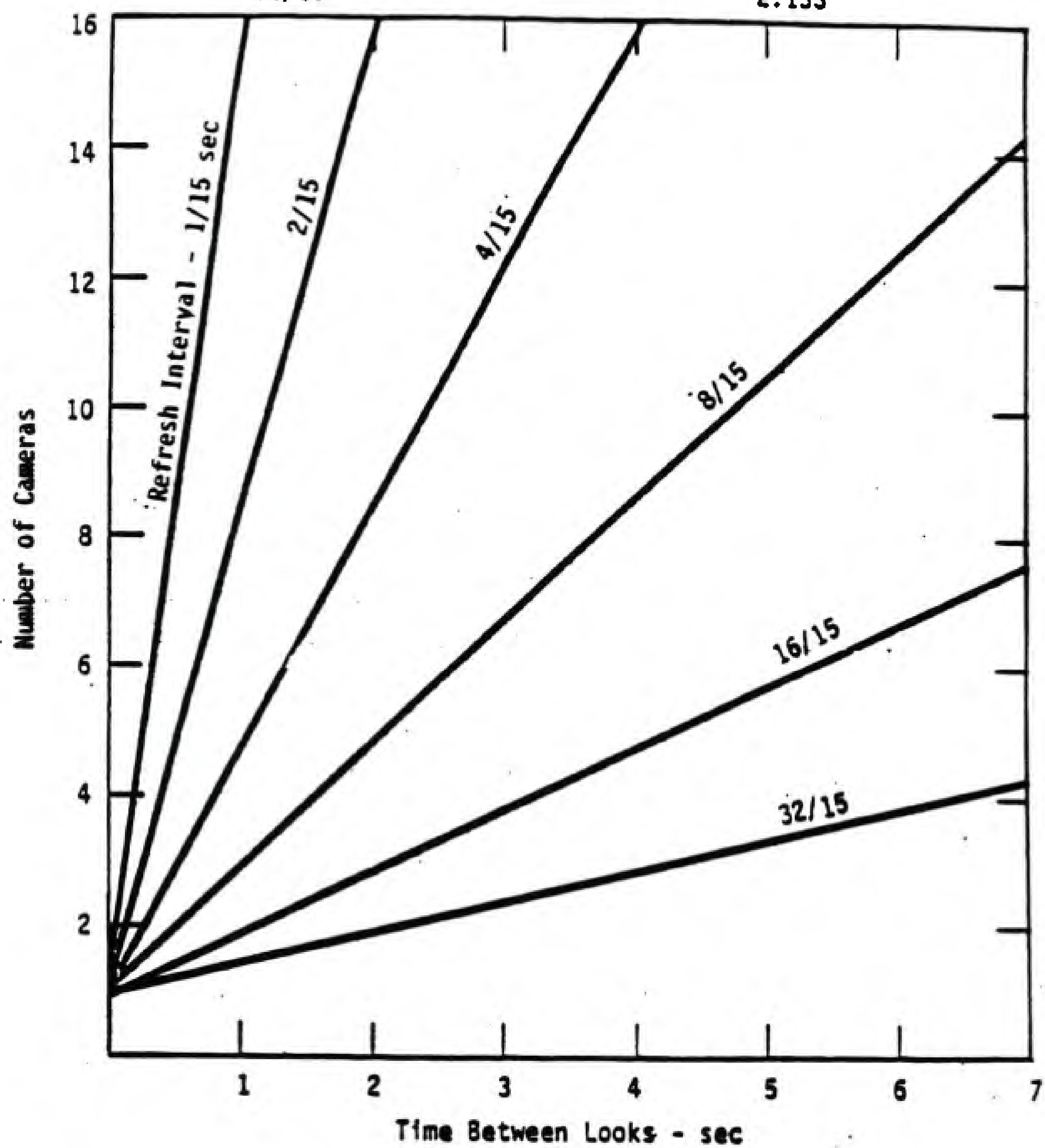
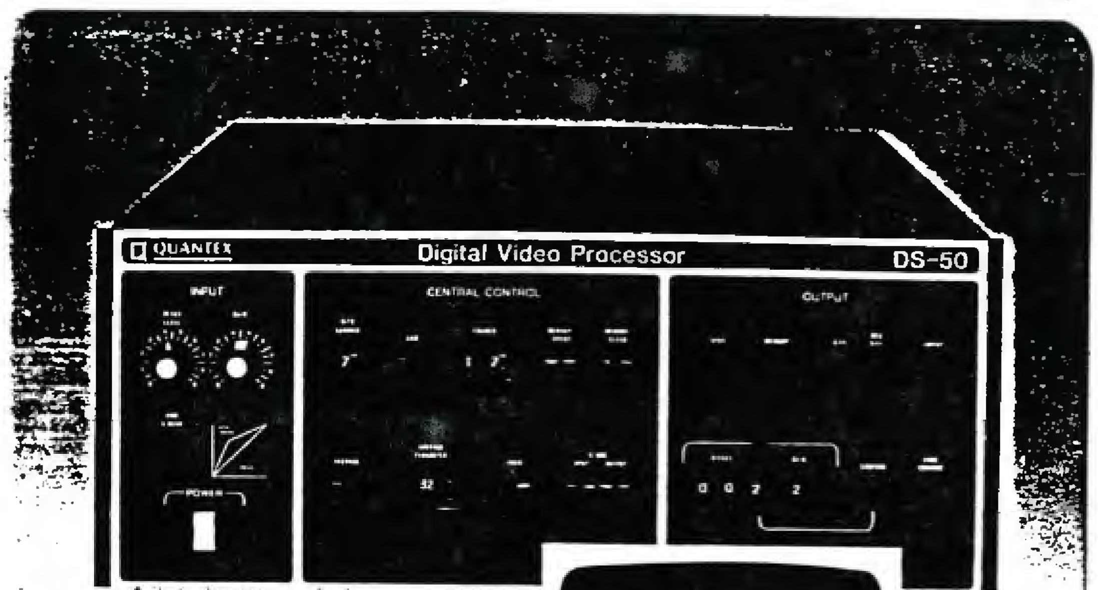
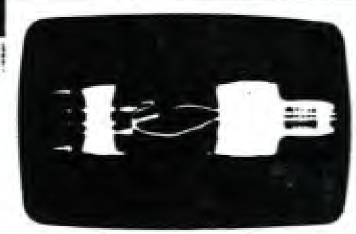


Figure 2.19. Detecting slow moving targets.

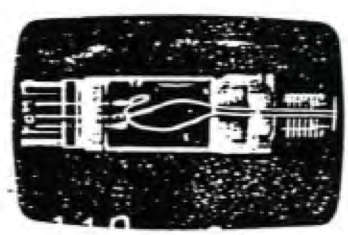
A second detector/processor, Model MDU-3, avoids the time-shared memory problem for a price. MDU-3 processors can handle up to four or eight input channels. Scene, reference frame and alarm map storage are provided for each channel so that all camera outputs are processed in parallel rather than in series. Resolution and refresh rates are the same as those for the MDU-2. The result is the same as having N MDU-2 processors, each using a single channel. The MDU-3 uses RAM memories, rather than the MOS shift-register logic used in the MDU-2.

Model MDU-4 motion detector is designed for indoor, relatively short range, applications. Versions are available for 8, 16, 24 or 32 input channels. MDU-4 also uses a RAM storage and processes all camera outputs in parallel. However, the scene contains 1024 resolution cells instead of 16,384. The area of the MDU-4 resolution cell is 16 times that of the MDU-2 or MDU-3.





X-ray image before processing.



X-ray image after processing.

WHY REAL TIME VIDEO IMAGE PROCESSING?

You should consider real time digital image processing whenever you need to:

- ☐ ***Improve the quality of a video image without delaying an important decision***
- ☐ ***Process an image that is changing***
- ☐ ***Eliminate the delay caused by off-line computer image processing or film developing***
- ☐ ***Automate your imaging process***
- ☐ ***Pre-process digitized video through hard-wired computer***

Figure 2.20. Quantex MDU Product Information.

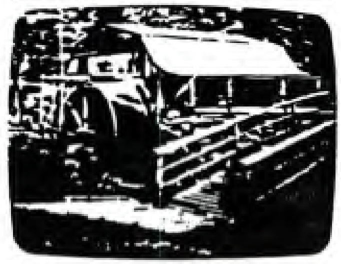
COMPARE TWO IMAGES OR SUBTRACT BACKGROUND—DIFFERENCE

The Quantex DS-50 can calculate the *digital difference* between the contents of memory and the next incoming video frame and store the difference in memory—where it can be displayed on a monitor or transmitted to an external computer. A useful application of this feature is that the DS-50 can act as a real time preprocessor that eliminates the stationary background before transmitting an image to your computer. This could greatly reduce the image processing time required by the existing image processing software in your computer. This function may also be used to compare an image with a stored reference image.

The DS-50 can also continuously display the *difference* between the contents of memory and the incoming frames when you select DIFF in the OUTPUT subpanel. This feature can allow you to precisely position an object by comparing its current position to a correctly positioned part, or detect movement (e.g., in surveillance). At any time the difference can be digitized and stored in memory by pressing the STORE OUTPUT key.

Difference

Difference



Same scene plus man

Difference after amplitude windowing

SPECIFICATIONS

VIDEO INPUT/OUTPUT

The DS-50 may be ordered to accept and play out video signals in either of two formats:

FORMAT

EIA Standard RS-170 525 lines	512x512 (512x490 visible)
CCIR Standard 625 lines	512x512 vertically centered

SYNC

Sync is extracted from the composite video input.

MEMORY SIZE (Spatial Resolution)

512x512 pixels

A/D CONVERTER RESOLUTION (AMPLITUDE RESOLUTION)

8 bits (256 levels) standard

MEMORY WORD DEPTH

12 bits standard

RANDOM ACCESS CYCLE TIME

1.6 microseconds per pixel

POWER

115/230 VAC, 50/60 Hz, 450 watts

DIMENSIONS

7" high, 17" wide, 21" deep

WEIGHT

44 lbs.

OPTIONS

IEEE STANDARD 488 INPUT/OUTPUT INTERFACE (Option 01)

This option interfaces the memory and the microprocessor to the IEEE 488-1975 Interface Bus. It allows transfer of digital image data to and from memory with random access. It also allows control of the Quantex processor from an external computer. Maximum data transfer rate is 1.6 microseconds per pixel.

RACK MOUNT KIT (Option 02)

Includes rackmounting slides. (Ears are included at no cost.)

REAL TIME VIDEO DATA INPUT AND OUTPUT (Option 05)

Real time *digital* video data may be provided at the rear panel in the form of eight bit digital words. Additional cost option. Input data is in place of A/D data. Output data is from D/A input.

Figure 2.20. Quantex MDU Product Information (Con't).

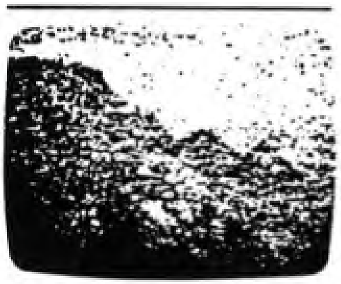
CAPTURE TRANSIENTS— STORE INPUT

The Quantex DS-50 will store the next incoming TV frame in its memory when triggered by the STORE INPUT pushbutton on the CENTRAL CONTROL subpanel or by an external electrical command. Events as short as 50 picoseconds in duration can be captured by synchronizing the grab command with a strobed image or a gated camera.

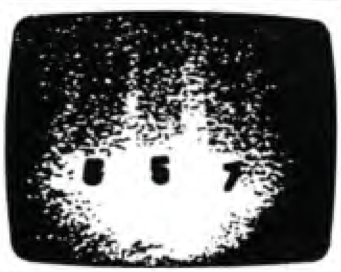
Grabbed television image of spray pattern from nozzle as it intersects a laser beam.

INCREASE CONTRAST AND REDUCE NOISE OF WEAK IMAGES—SUM

Summing (digital integration) is analogous to a time exposure with film. Since information in the video signal sums linearly while noise sums quadratically, summing improves signal-to-noise ratio by $\sqrt{N}$ where N is the number of frames summed. With the Quantex DS-50, the number of frames to be summed is selected by front panel switches. Quantex *Application Note 13* describes summing in more detail.



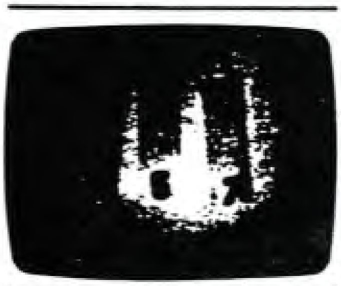
Single Frame (direct camera output to monitor)



ASME Penetrameter images on 3/8" steel before processing.

Note: This scene was taken at night using a low light level camera. Because of the low signal level input to the image processor, 64 frames could be summed without changing the sum align. By shifting the sum align 2 places (i.e., setting at 5 instead of 7) 256 frames could have been summed if required.

Picture after 64-frame sum



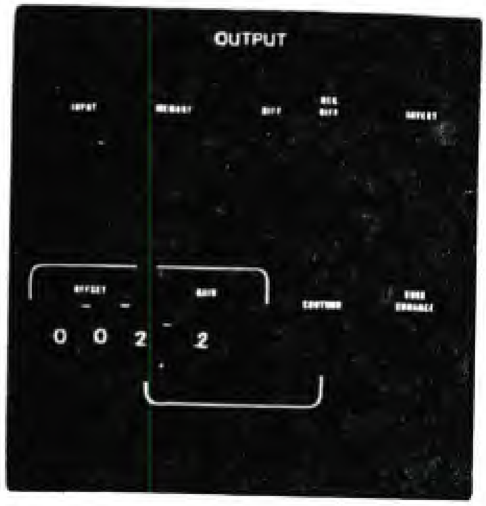
Same image after summing 120 frames showing 2-4T.

Figure 2.20. Quantex MDU Product Information (Con't).

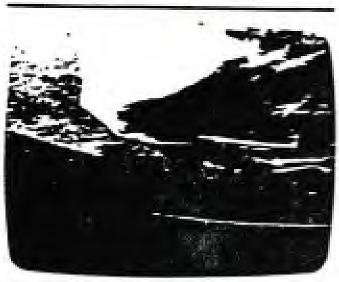
[illegible] WHILE [illegible] VIEWING [illegible] IMAGE

Averaging reduces noise because random fluctuations around the mean value cancel each other out as the frames are averaged together. The Quantex DS-50 performs an exponentially weighted sliding average with an averaging time constant of N/30 seconds. Averaging improves signal to noise ratio by $\sqrt{2N-1}$. N may be set to 2, 4, 8, 16, 32, 64, or 128. When N = 128 noise is reduced to 1/16th of its unprocessed level.

Averaging introduces a lag which causes smearing if the image has features that move. By viewing the processed image while averaging, you can select N so as to optimize the tradeoff between noise reduction and lag. For a more detailed discussion of the averaging function, refer to Quantex *Application Note 12.*



Unprocessed Image.



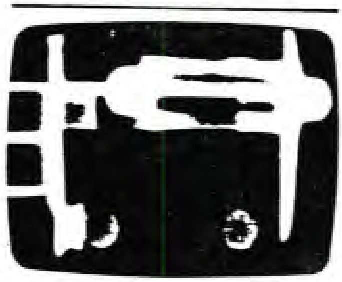
Same image after Averaging; N = 16.

EDGE ENHANCEMENT

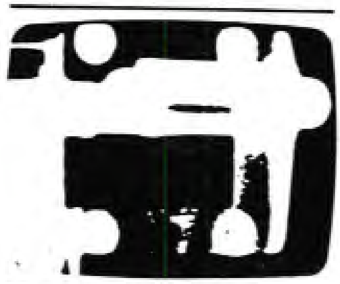
Edges can be enhanced by selecting EDGE ENH on the OUTPUT subpanel. The DS-50 performs this enhancement by taking the difference between the image and itself shifted one pixel in the X and Y directions.

AMPLITUDE "WINDOWING"

OFFSET in the Video OUTPUT subpanel will shift all (up to 12 bits) of the memory gray scale levels below the selected level to black. GAIN can then be set to expand the contrast of the video display or a section of the gray scale above the level selected by offset. Gray scale levels above the range of GAIN will be forced to white. Thus the DS-50 can expand any section of the gray scale to full black/white contrast.



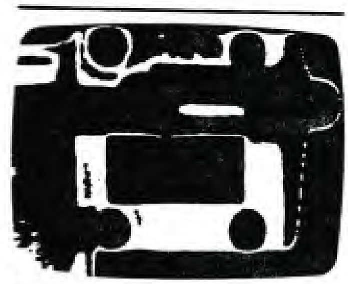
Unprocessed radiograph of a precision aluminum casting.



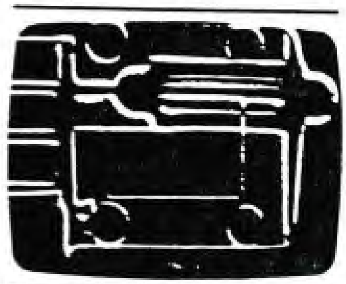
Radiograph after Windowing with GAIN of 16, OFFSET of 32.

AMPLITUDE CONTOURING

By selecting C'TOUR on the VIDEO OUTPUT subpanel and adjusting the OFFSET control, a selected range of memory gray scale levels may be displayed as amplified gray scale while all other gray scale levels are displayed as black. The result is the same as in amplitude windowing except that gray scale levels greater than the range of GAIN are set to black instead of white.



Radiograph after Contouring with GAIN of 16, OFFSET of 32.



Radiograph after Edge Enhancement.

Figure 2.20. Quantex MDU Product Information (Con't).

2.6 HUMAN FACTORS

The test program is designed to develop lighting standards for piers and not to study the role of human behavior in pier security, operations and safety. A discussion of human behavioral issues is pertinent.

2.6.1 Security

The common human role in physical security, as in this application, is the surveillance of an area to detect and assess threats. In the real world, there are essentially never threats so the job is unique in the lack of job performance feedback. There is typically no means of rewarding attentiveness and no means of punishing lack of attentiveness. There is no motivation, but there is plenty of boredom. Security guards think, read and stargaze. Discerning a threat in the midst of other activities is very difficult, but discerning a threat in a tranquil scene is still a rarity due to the lack of attentiveness. Security guards typically have shifts approaching 8 hours, while radar and sonar operators have shifts of 20 minutes to avoid such problems.

It is possible to test the lighting influence upon visibility (assessment), but to strive for a test of detection would cost enormously more due to the complexity of the human factors issues.

2.6.2 Operations and Safety

Conventional time-motion studies yield efficiency data helpful in redesigning work objectives, flows and supporting machinery. Lighting levels influence task performance speed, but so do fatigue, motivation, repetition, fear, and other human factors. Pier operations and safety are undoubtedly intertwined. Personnel will not attempt to perform a task faster than believed safe. Lighting will therefore probably speed up activity <u>because</u> it is safe to speed up.

Conducting controlled experiments of task performance rates is not recommended. This is due to the expectation of large variances between individuals, and the expected large variance between the normal <u>team</u> performance rates on macro tasks (such as reported in Reference 2) that depend upon fatigue, motivation and training. It is entirely plausible to anticipate that human factors variances are greater than lighting level influences upon the task performance.

SECTION 3

PIER LIGHTING TEST PROGRAM

This section introduces the extent of the pier lighting test program, designed to provide a quantitative basis for Navy Pier Lighting Specifications. The test program began in April 1988 and is completed with this report. Originally, scheduled for field test operations to be performed as early as June 1, construction delays allowed actual field testing to be performed between November 28 and December 8.

3.1 PURPOSE

Tests will determine if the Pier Lighting Thresholds established in the TEMP* and summarized in Table 3.1 are adequate and if variations from these levels will

Table 3.1. Navy pier lighting operational characteristics*.

FACTOR	TENTATIVE OPERATIONAL LEVELS	
	GOAL	THRESHOLD
1. ILLUMINATION LEVEL		
a. work area	3–6 fc (4.5 fc average)	2–5 fc (3.5 fc average)
b. nonwork area	2 fc average	1 fc minimum
c. general safety	1 fc average	0.5 fc minimum
2. GLARE		
a. vehicle traffic	none	none
b. ship traffic	none	none
3. ENERGY CONSERVATION power consumption per square yard per hour	0.9 watts/yd/hr	1.5 watts/yd/hr

*Test and Evaluation Master Plan (TEMP) for Establishing Pier Lighting Criteria, Naval Civil Engineering Laboratory significantly improve or decrease:

productivity,

safety, or

security.

The end products of this research are recommended lighting levels for pier nighttime operations, safety and security.

3.2 TESTED LIGHTING SYSTEM

The system used was selected because it can be adapted to simulate a wide range of test conditions. It can provide a range of illumination levels; the light fixtures can be lowered to evaluate the effects of glare; and it offers minimal interference with pier activities, since only three standards are employed. Figure 3.1 provides a typical pole detail planned for use.

Specific lighting assemblies include:

1. Poles 1 and 3. Six 400 watt NEMA type 2 × 2 and two 400 watt NEMA type 4 ×4 power spot, HPS floodlight fixtures mounted on lowerable ring.
2. Pole 2. Twelve 400 watt NEMA type 2 ×2 and four 400 watt NEMA type 4 ×4 power spot, HPS floodlight fixtures mounted on lowerable ring.

The system consists of clusters of power spot floodlights mounted on three 100-foot, galvanized steel poles positioned as shown in Figure 3.2.

Lowerable hoist rings will be used in conjunction with 100-foot poles in order to permit the lighting assemblies to be lowered for varying lighting levels during the tests.

The design of the pier high mast, perimeter lighting system will include:

Photocell Switches, either series circuit or individual lamp type. The unit will turn on below three footcandles and off at three to ten footcandles. A time delay will be included to prevent accidental switching from transient light sources.

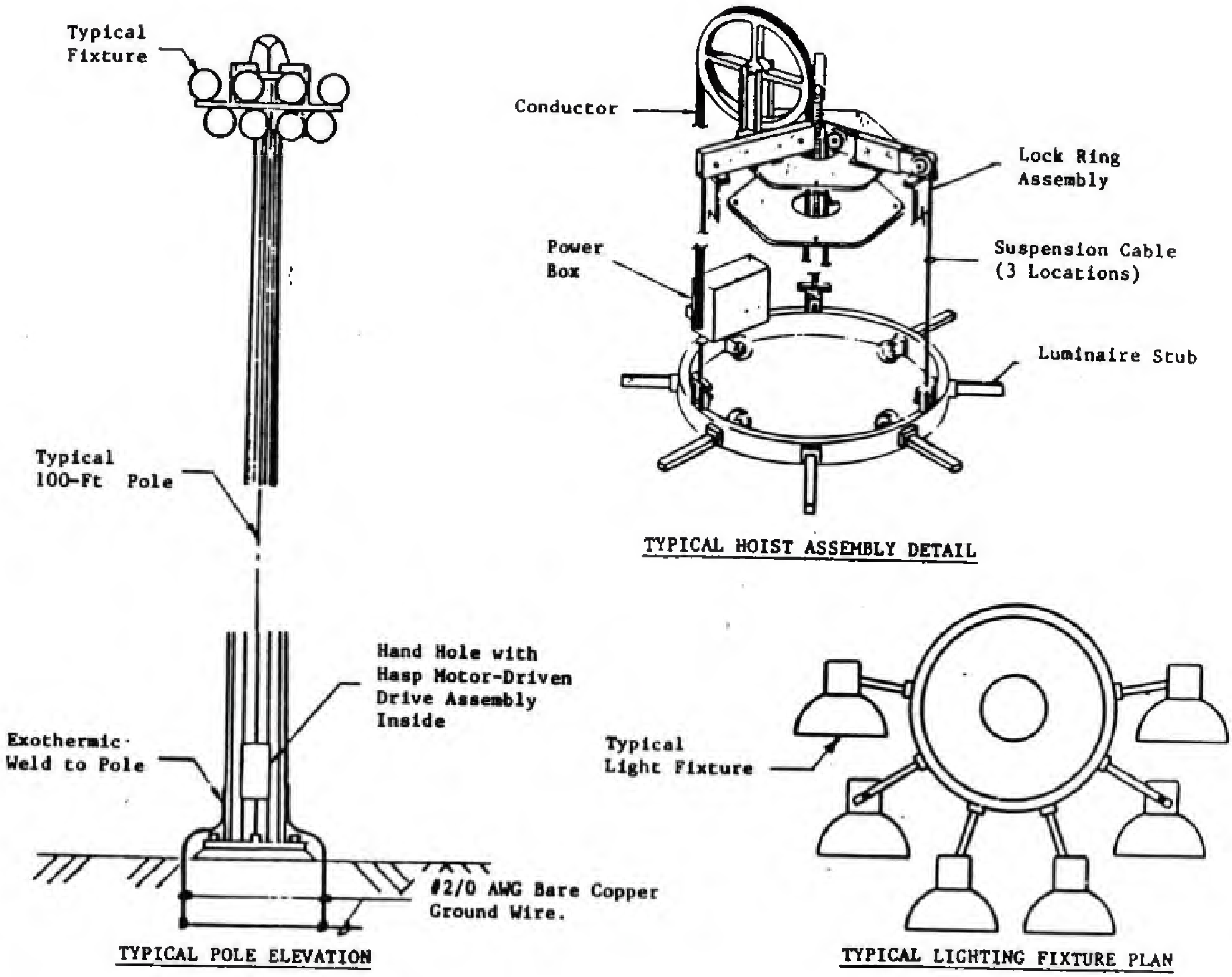


Figure 3.1. Typical high mast light pole with floodlight fixtures and lowerable hoist ring.

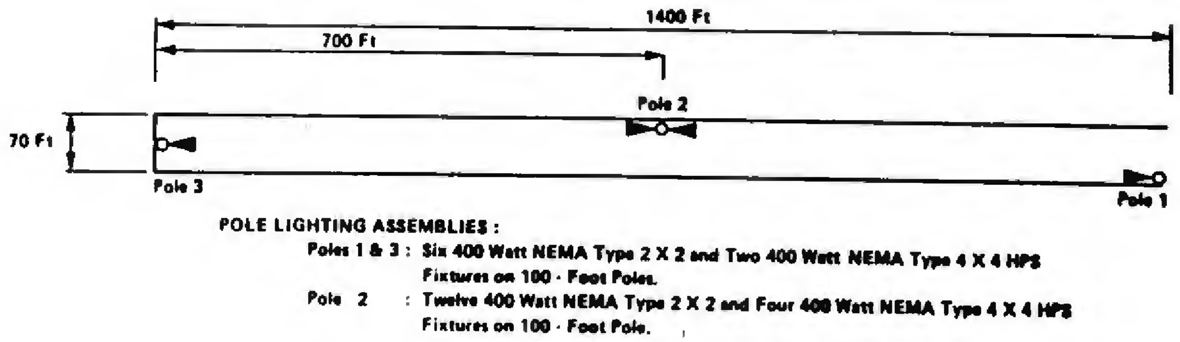


Figure 3.2. **Lighting system using three high mast poles and floodlight fixtures.**

Luminaires, 400 watt HPS, with noncorrosive hardware and independent aiming devices.

Figures 3.3 and 3.4 show the performance of a typical (GE Lucalux) High Pressure Sodium NEMA type 1 luminaire.

3.3 TEST SITE

The tests were performed on and around Pier 5 at the Naval Station at San Diego, California. This pier, shown in Figure 3.5, is 1261 feet long, 60 feet wide and 700 feet from either neighboring pier. While subject to rain and fog conditions, this site is not subject to snow.

A site survey was performed on April 9 and 10, 1987 by personnel from MRC and the Task Leader from NCEL, Mr. Gerald Milmont. Day and night activities at Pier 5 and other piers were witnessed and interviews of Physical Security Chief Raymond Moody, Assistant Staff Civil Engineer, Mr. George Winnett, and Port

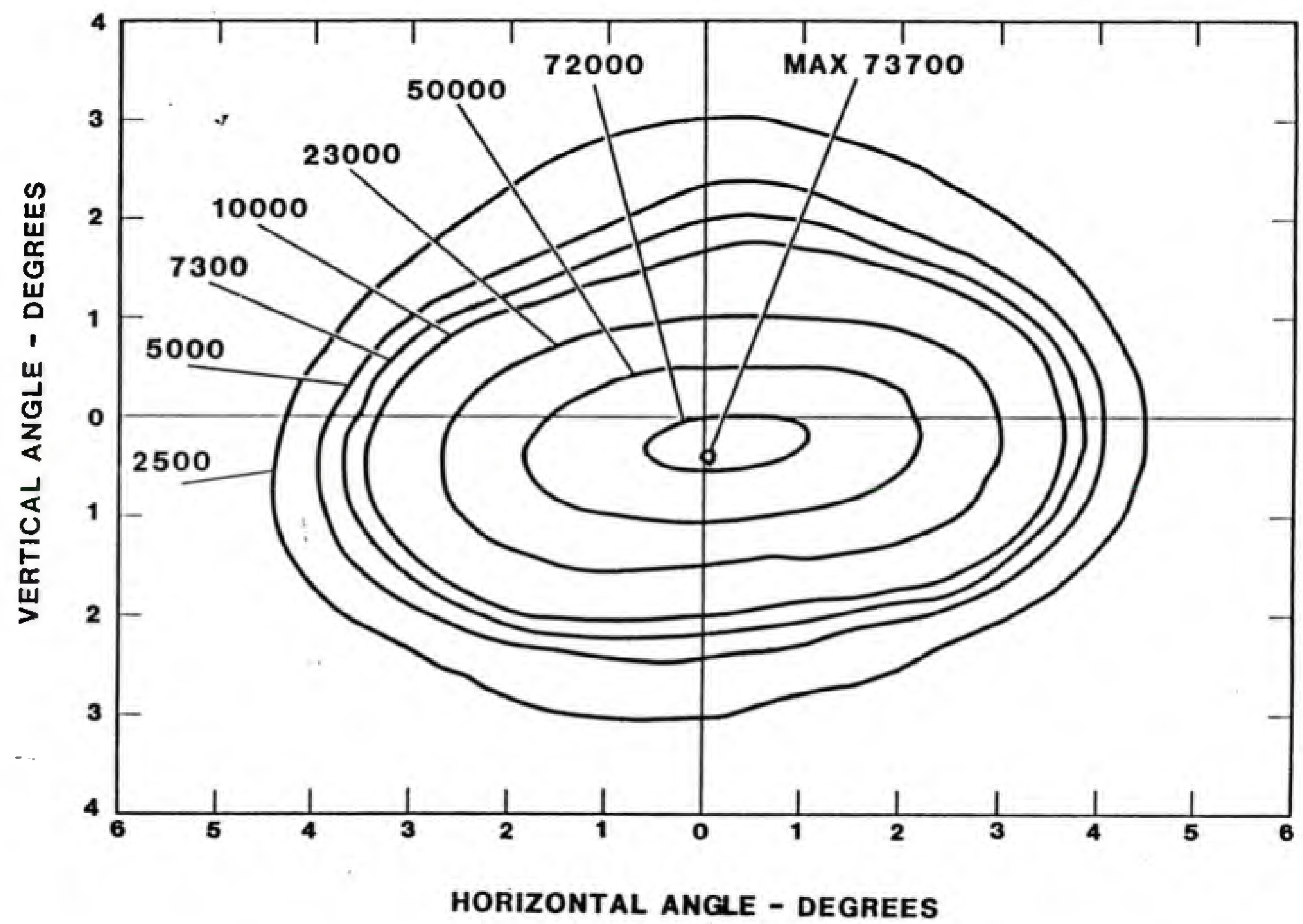


Figure 3.3. Measured isocandela contours for GE H7616 lamp.

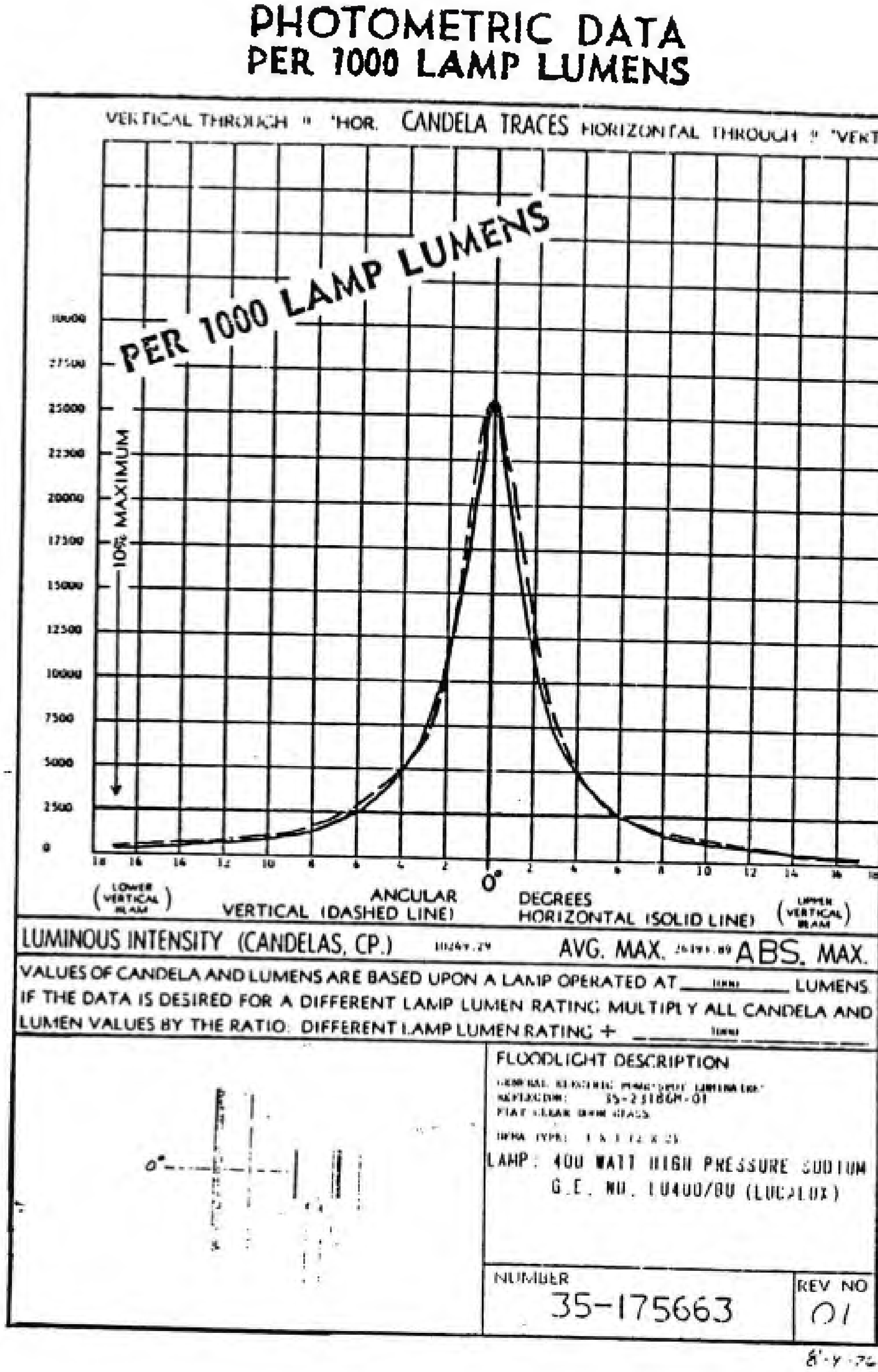


Figure 3.4. **Photometric data for a high pressure sodium lamp in a power-spot reflector.**

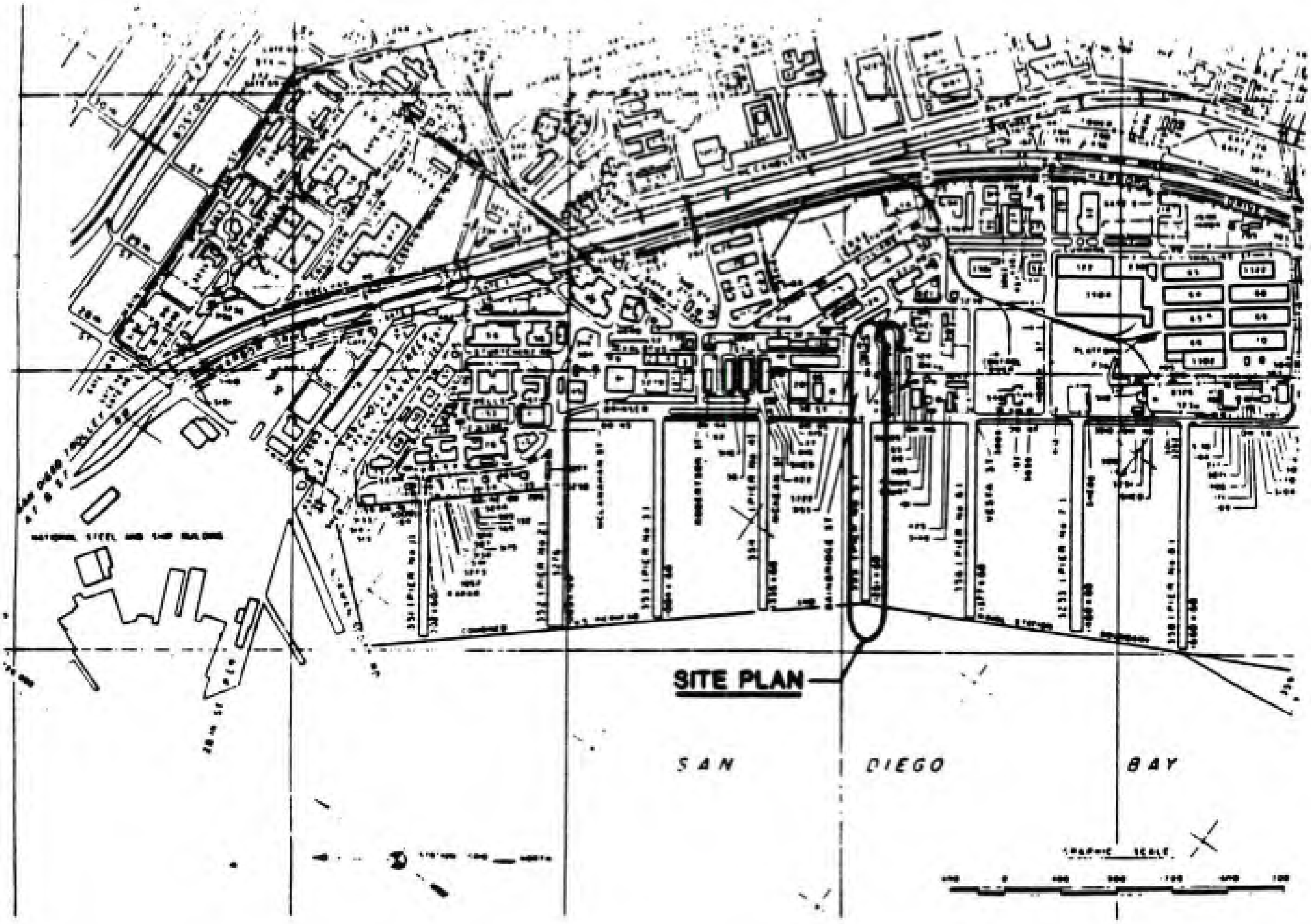


Figure 3.5. Test pier site plan .

Operations officer, Mr. Warner. This site survey was crucial to understanding of the issues and helped greatly providing a focus for test planning purposes.

The site visit revealed that pier security currently consists of two pierhead access control guards and a single roving guard, all supplied from the moored ships' crew. Each ship also has a quarterdeck ship access control guard. All lighting is supplied by the ships except for 60 watt bulbs along the edge of the pier. At noon on a clear day, it is almost beyond the realm of human eye resolution to discern a stationary standing human from one end of the pier to the other. There is a continuous stream of personnel on foot along the pier. There is little more than access control security on the pier surface, and that is not really limited by lighting intensity.

The NAVSTA San Diego security department has ordered two patrol boats and is intending to operate one of the two on continuous patrol, viewing the water area between piers from the San Diego Bay 24 hours per day. The patrol distance between Piers 1 and 13 is approximately 1 1/2 nautical miles. A spotlight mounted on the patrol boat is felt to be undesirable since it would make the patrol boat too good of a target. The NAVSTA authority ends at a line drawn between the ends of piers. The U.S. Coast Guard exercises authority over San Diego Bay. When this patrol boat concept is implemented, the crew will be in a position to view the water surface between piers roughly twice per hour for around 2 minutes. There is no current or planned watch on the outboard side of each ship, either day or night. Only sidearms are immediately available from shore and pier guards. The patrol boat and ships magazines can provide slight increases in firepower within 5 minutes.

We observed that a large number of ambient night lights (including ships lights, parking lighting, building lights, etc.) created specular reflections on each water ripple or wavelet when viewed from the water. Thus a bright/dark streaked pattern was quite noticeable. It becomes an immediate point of debate whether this ambient lighting (certainly less than 0.05 foot candles) would provide a high probability of detection without additional lighting. It was further observed that AD class ships typically have 4 HPS lights high on each mast. This caused water illumination in the range of 0.05 to 0.5 foot candles and was noticeable.

Walking on the pier with lighting levels varying from 2 to 0.02 footcandles we did not feel threatened in any way from a safety point of view. There was a 3/4 moon during the visit. Attempts to interview the Safety officer were unsuccessful due to schedule conflicts, but other NAVSTA personnel knew of no crisis in pier safety.

Operations were observed both day and night. Dockings, loadings, mobile crane operations including brow placement were viewed. Our visit was obviously not during a period of peak operational activity. Nighttime operations were performed in roughly the same time line as in daytime. Crane operators were observed rubbing their faces to stay awake during night operations. Mr. Warner indicated that day shift personnel were "on-call" for night duty.

The interview also revealed that every few months when major fleet movements overlap, night operations increase dramatically for several days duration. There is the opinion that during such periods, night lighting of piers would offer productivity increases.

3.4 TEST INSTRUMENTATION AND PLANNING

3.4.1 Concept

The security test concept was based upon that used for the 1981 lighting test performed for the US Army MERADCOM by Mission Research Corporation entitled, "Lighting and Artificial Ground Cover." It uses personnel to observe controlled intrusion activities performed at several locations at programmed times on the pier surface and the water surface. These observer personnel are placed at various locations expected to be of interest in order to determine the sensitivity of observation success rate to observer location as well as lighting intensity. CCTV cameras are placed at some difficult to reach (high) locations as well as next to some observers, in order to reserve advantages of observer locations and compare effectiveness of CCTV aids with direct human observation.

Since many trials of active security testing can be programed into a relatively short period compared to that required for repeated pier operations activities or even accidents, the same CCTV cameras are designed to passively observe the pier over a long period to obtain relatively covert operational and safety data.

After reduction of the test data, a team of experts in security, operations, human factors, and safety will interpret the results.

Passive Recording

The CCTV system is designed to record on a multiplexed video recording system 24 hours per day for a three month period in order to quantify the time required to accomplish various pier operations without affecting the performance of the participants. The CCTV cameras are visible but barely so, and its presence over an extended time is planned to allow Navy personnel acclimate to it, performing their tasks normally. In differing lighting conditions it was hoped that the timelines of the jobs would change in a manner relatable to the illumination.

It is important to note that night mooring and departure of ships is discouraged at the NAVSTA for purposes of workload and of seamanship. It was therefore particularly important not to "stage" night operations, since the resulting timelines would likely be the result of a high degree of motivation, being perceived as a timed drill. The video recording capability was fielded with a time lapse capability allowing for time compression and for a two day period per tape to conserve test manpower. It also allowed for imprinting the time and date on the scene. This CCTV system therefore allowed for obtaining all the needed data without significant contamination by the presence of test personnel. It also minimized the cost of labor in recording and reducing the resulting data.

This system was provided and installed under the direction of the Navy Electronic System Engineering Activity (NESEA).

Threats

The vision test needs to relate to the Blackwell tests and is easily done by varying the size, speed, and tactic of the intrusion actor. This is accomplished by conducting tests at different distances along the pier, performing several different motions, and rehearsing the speed of movements to be predictably slow or fast.

Pier security tests were planned to involve three separate intrusion ranges on the outer half of the pier. This allows for a difference in angular subtense (size) of the threat object to the viewer as well as a way of testing the observer honesty and confidence. The actual test arrangement is depicted on Figure 3.6, with intrusion Range A nominally 600 feet from the head of the pier, Range B nominally 900 feet from the head of the pier, and Range C nearly 1200 feet from the head of the pier. Precise distances corresponding to the above were 646 feet, 889 feet, and 1132 feet. A blind was fabricated or already existed at these locations to prevent an observer from seeing an intruder before the intrusion began. Cameras and observers were located relative to these ranges to view at distances of roughly, 300, 600, 900, and 1200 feet.

The pier intrusions consisted of either a 15 feet per second "run," a "crawl" or "roll" at 1.5 feet per second, a motionless "stand," or a no action "false alarm." The pier is 60 feet wide, has 15 feet between each side and a red "fire" stripe, and has 4 feet between each red stripe and a yellow "road" stripe to define a walkway. The intrusion is nominally between the red stripes. Intrusions were performed at one minute intervals.

Water intrusions were also conducted on the portion of the water shown in Figure 3.7 as being closest to Pier 4 and opposite the ranges A to C. Early planning had favored the fourth of the water nearest the outer half of Pier 5. On site inspection changed that when it became obvious that large moored ships at Pier 5 caused much of that area to be shadowed from the 100 foot lighting. Evidently, in order to illuminate the water surface, one must count on the lights from neighboring piers to operate in a "buddy system" in securing the water. Water intrusions consisted of two ranges: one parallel to the pier and another perpendicular to it. Two teams of SEAL trainees in inflatable "zodiacs" conducted intrusions consisting of either; a "slow boat" at 1

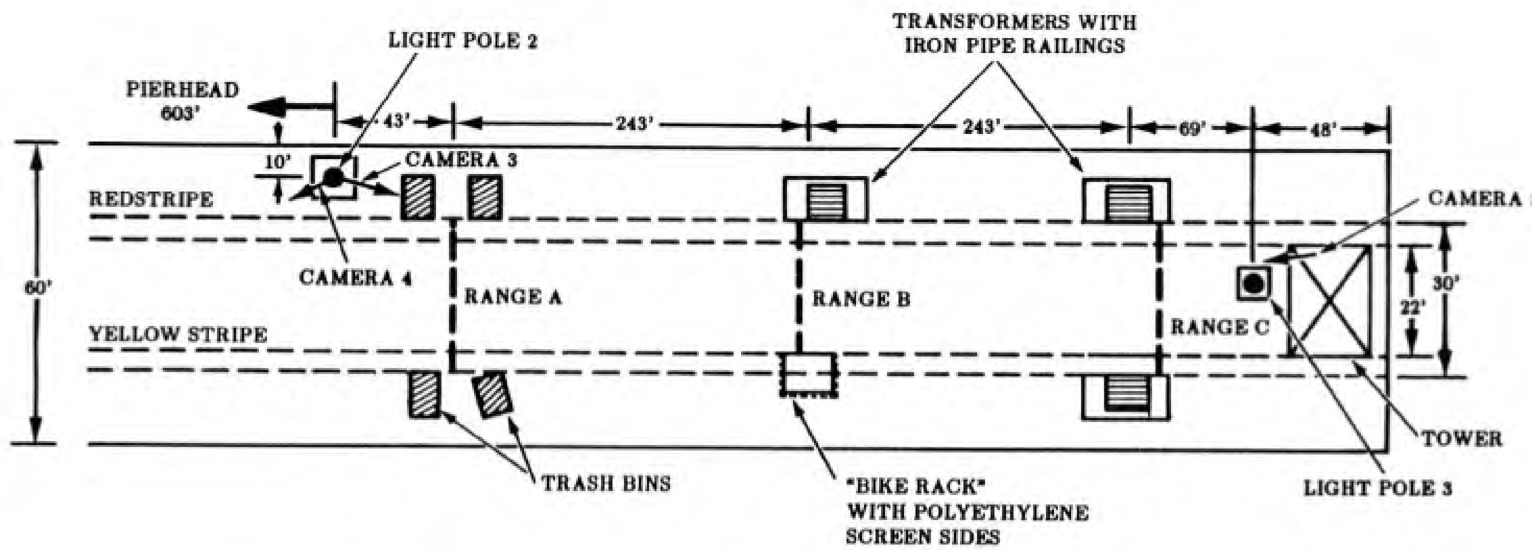


Figure 3.6. Pier Intrusion Test Configuration.

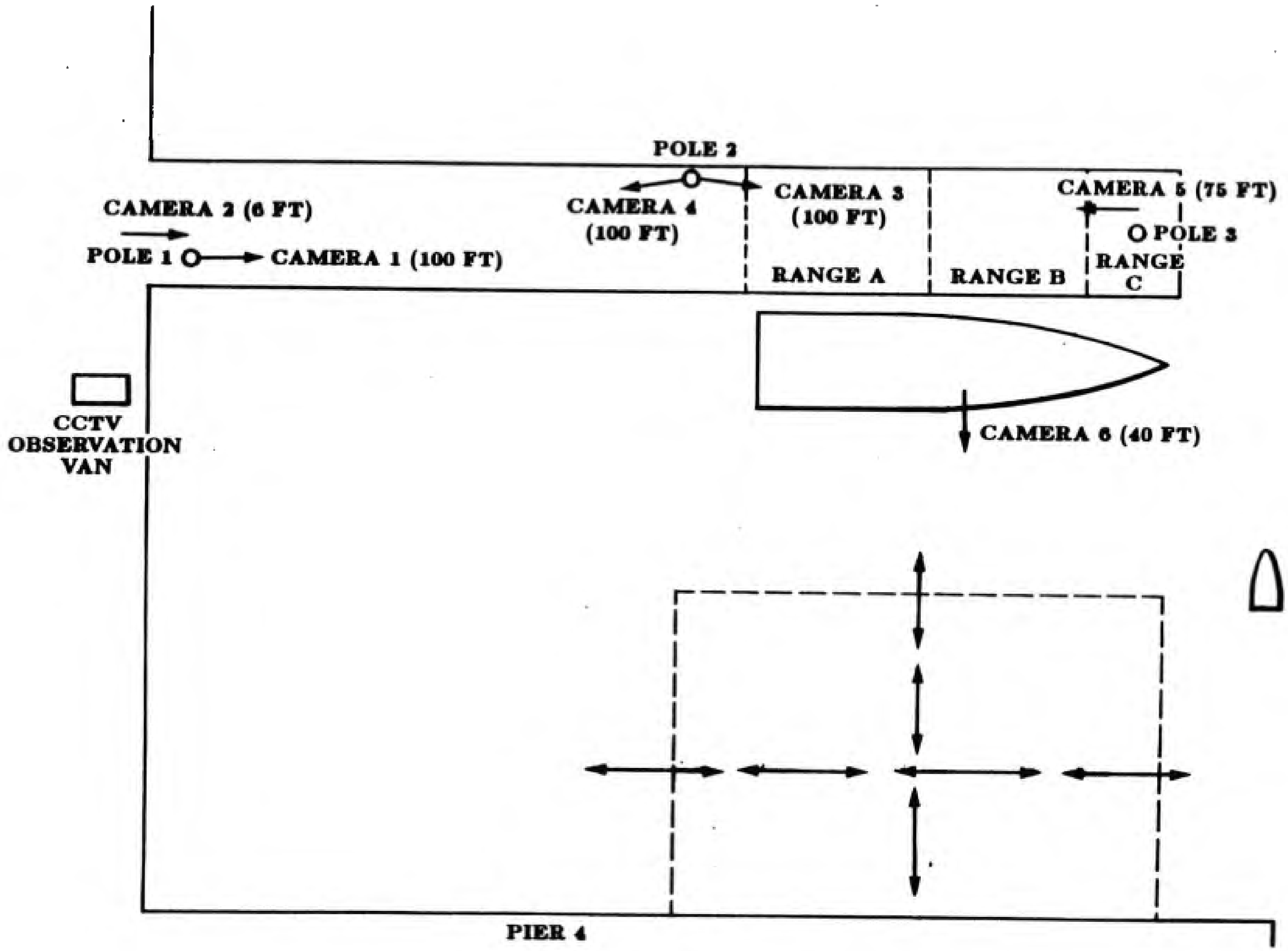


Figure 3.7. Test Site Layout.

knot, a "fast boat" at 5 knots, a "swim" at 1 knot, a motionless "stop boat," or a no action "false alarm." Intrusions were performed at 6 minute intervals.

Viewing Aspect

The test plan regarded the viewing aspect as potentially equally significant to the lighting intensity. Normal pier security uses a pierhead guard for access control by badge inspection. He is aided by a single roving patrol that walks the length of the pier at intervals. One major question was whether the pierhead location would suffice for securing the entire pier. Another question was where were the best combination of locations for securing the pier and water.

In order to answer this question relative to the pier surface, CCTV cameras were placed near the top of the 100 foot light poles, to look down on the pier surface. These are described in some detail in Section 3.4.3 below.

The water security test used these same cameras, but skewed them to view the water area. Also, a camera and a person were added to the bridge of a ship moored on pier 5 across from the test zone as shown in Figure 3.7. Finally, an observer was placed upon the police boat moored around 300 feet out in the channel between the piers. This was done in order to provide data regarding the future effectiveness of planned patrols using the patrol boat in the channel.

Lighting

The lighting system was to be tested in high power and low power modes. It was also to be tested for effectiveness at 100 foot and 50 foot heights. The luminaire aiming was generally left as delivered-aimed down to limit glare. Eventually, at the end of the pier surface tests and as the luminaires were re-aimed out toward the water test area, a "glare lighting" aiming concept was introduced to provide very uniform pier surface illuminances at the expense of introducing high glare characteristics.

Scripts

Early in the planning phase it was recognized that many intrusion trials would be necessary in order to derive statistically significant results. With around 20 personnel involved in each trial, scripts were preferred over radio communication and individual direction. Scripts were generated to the second, involving 428 intrusions per night. Three different scripts were randomized in order to prevent predictability by the observers. The scripts directed which intrusion range was to be active, which tactic was to be executed, and how many seconds of delay was to be introduced after the observer started looking.

3.4.2 Schedule

The revised test schedule as of August 1988 is shown in Figure 3.8. It shows the planned period of passive recording before the active security tests and an October completion of active testing. The schedule was still dependent upon limiting the lighting construction delay to under 3 months.

The lighting construction and acceptance and instrumentation installation was completed in September. The week of September 19 to 23 saw the CCTV installation essentially complete. October 26 to 30 the test team briefed the Navy enlisted personnel, made final adjustments to the instrumentation, and conducted a day and night dry run for checkout and training purposes. During this time, further difficulties with the lights were encountered, interfering with the raising, lowering and camera performance. The entire Navy and civilian test team was called off the scheduled October 2 test start in order to affect repairs to the lighting.

On November 28 the team was recalled to begin tests. One camera was still inoperative at the 1300 hours start of testing. At 1506 the contractor arrived to repair the pole and camera power, turning off all power and causing the cancellation of ongoing tests. At 1800, November 28, 1988 all lighting and instrumentation systems were operational and tests underway.

3.4.3 Instrumentation

The test site was instrumented with CCTV in order to obtain security data on the benefits of various observation vantage points and to inobtrusively record pier operations in alternate lighting configurations.

<u>CCTV Cameras</u>

A total of six CCTV cameras were deployed during the test program. Three of these were attached to the light rings that could be raised to a height of almost 100 feet. One was afixed to the tower at the end of the Pier 5, around 75 feet high. Two others were used alongside human observers to provide a direct comparison of CCTV and eyesight from the pierhead surface and from the area of the bridge of moored ships. The following Table 3.2 lists the camera designations along with their general specifications and locations. Figure 3.9 shows the locations pictorially.

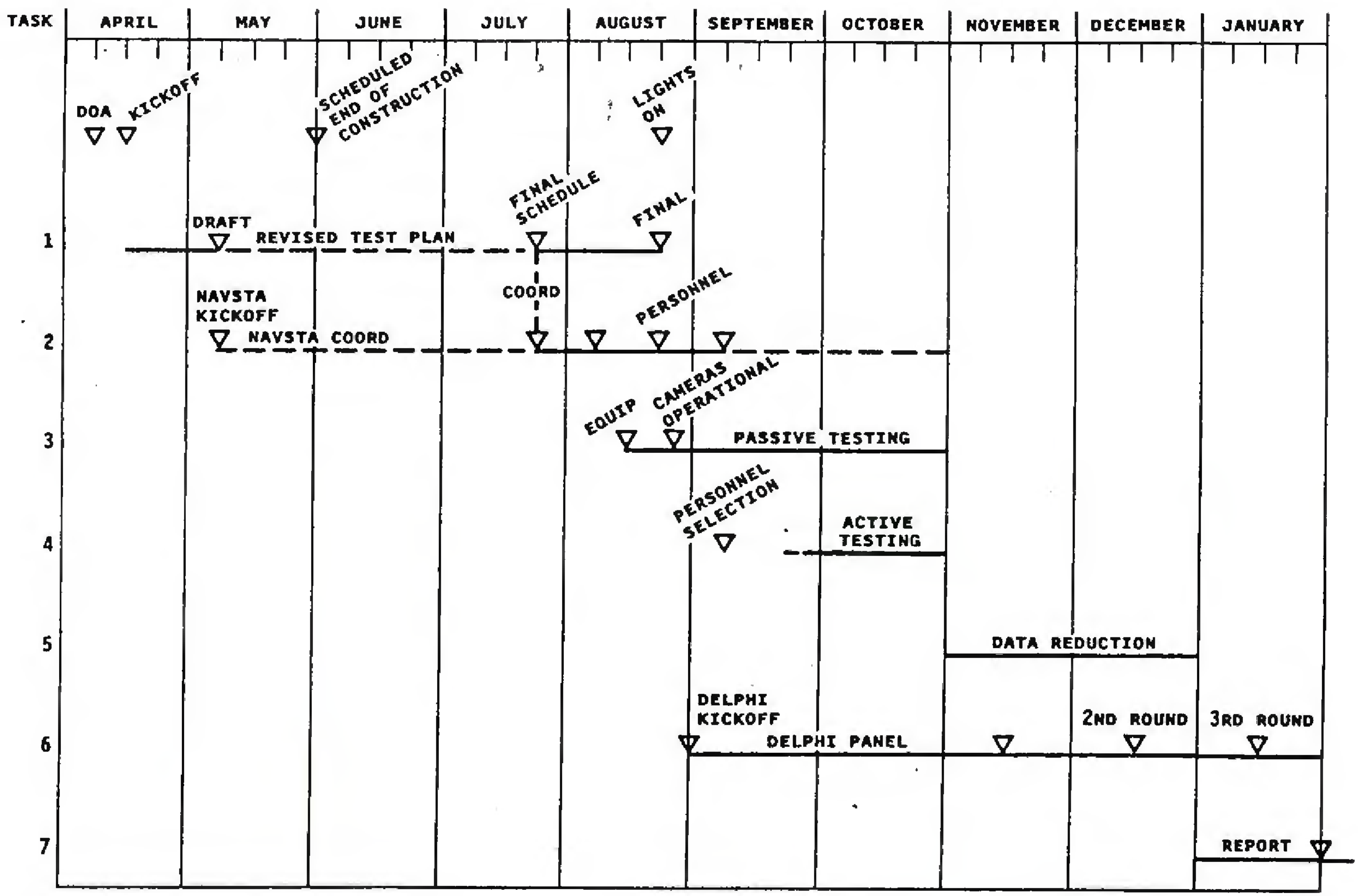


Figure 3.8. Summary Program Schedule.

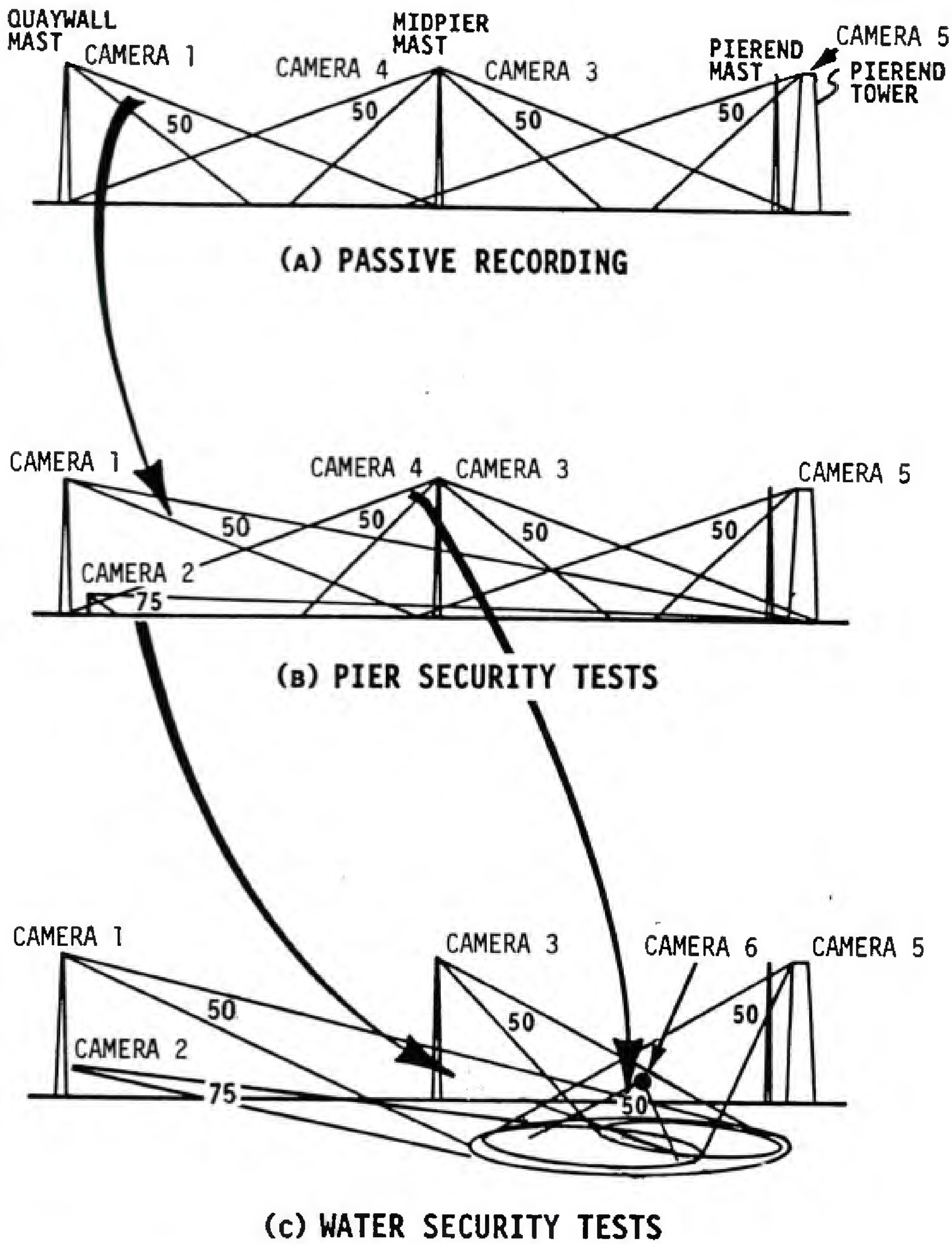


Figure 3.9. CCTV camera deployments.

Video Display Van

Four video monitors were located in a van near the head of Pier 5. Figure 3.10 indicates the design and layout of this van. Important features are video switching to allow any camera to be displayed an any monitor, curtains to visually isolate observers from one another, and headset radios to acoustically isolate observers from one another. A video recorder multiplexed signals from all six cameras and recorded time lapse imagery with time of day displayed. Figure 3.11 shows the one line diagram for the video recording equipment.

Table 3.2. Camera Deployments and Specifications.

CAMERA	FOCAL LENGTH (mm)	HEIGHT (feet)	LOCATION	VIEW
1	50	90	Pole 1 (Pierhead)	Out
2	75	6	Pierhead	Out
3	50	90	Pole 2 (Mid Pier)	Out
4	50	90	Pole 2 (Mid Pier)	In
5	50	75	Tower (Pier End)	In
6	50	30	Ships Bridge	Water

3.4.4 Subjects

A large number of Navy personnel were provided to support this test program. One group was provided by various NAVSTA San Diego organizations to support pier security tests. Another was provided by the NAVSPECWARCEN seal training organization to support water intrusions. In all, some 36 personnel were directly involved in the intrusions and observations.

Physiology

All NAVSTA personnel (22) were examined by the base medical clinic optometrist for visual capabilities on September 15, 1988. Standard visual acuity tests were performed on each and those with less than 20/20 vision were fitted with corrective glasses. Additionally, all were tested for contrast sensitivity (described in Figure 3.12. Personnel with significant visual difficulties were assigned to the intrusion team, except for a controlled few with marginal contrast difficulties worth comparing with others.

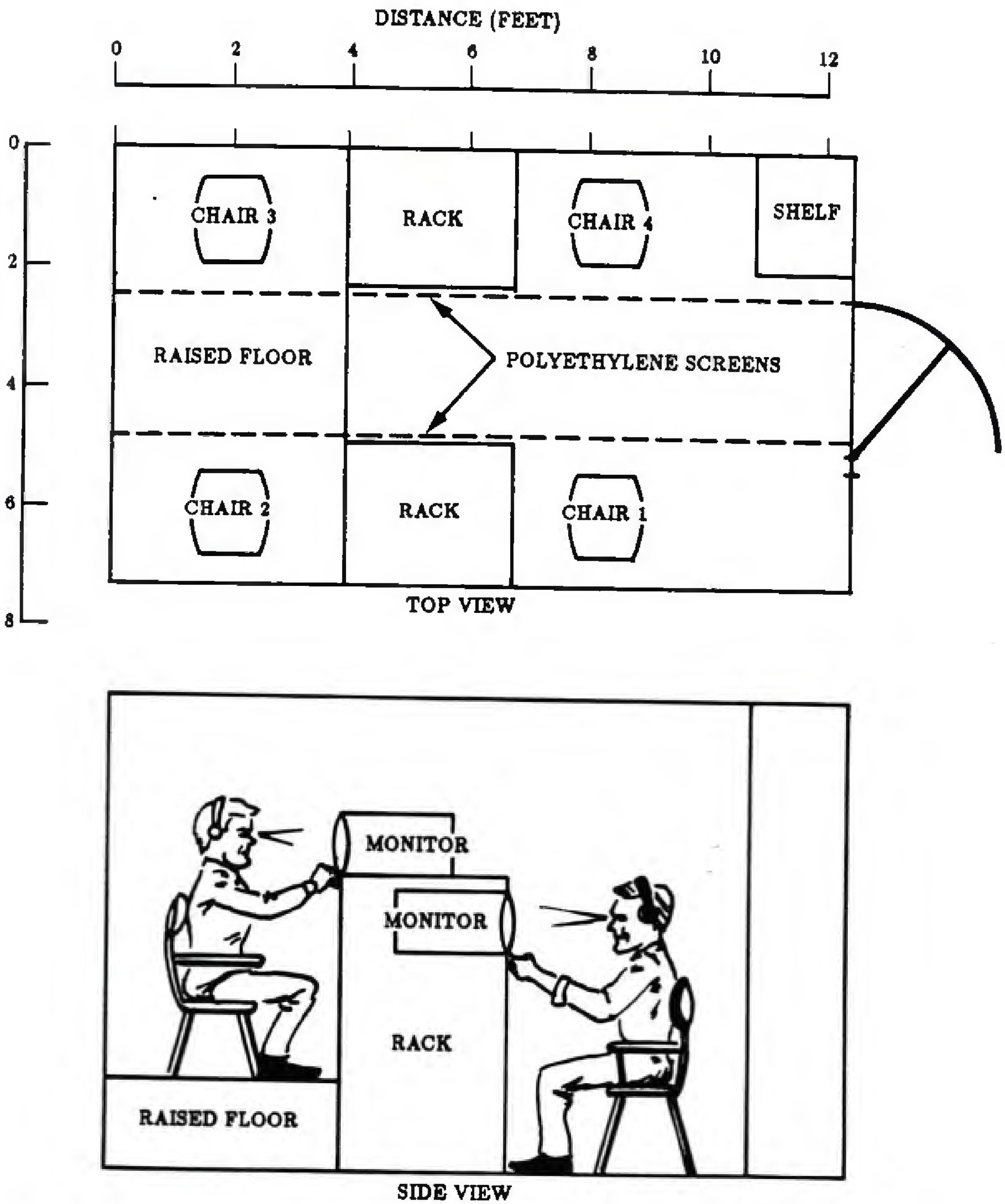


Figure 3.10. Video Recording Van Layout.

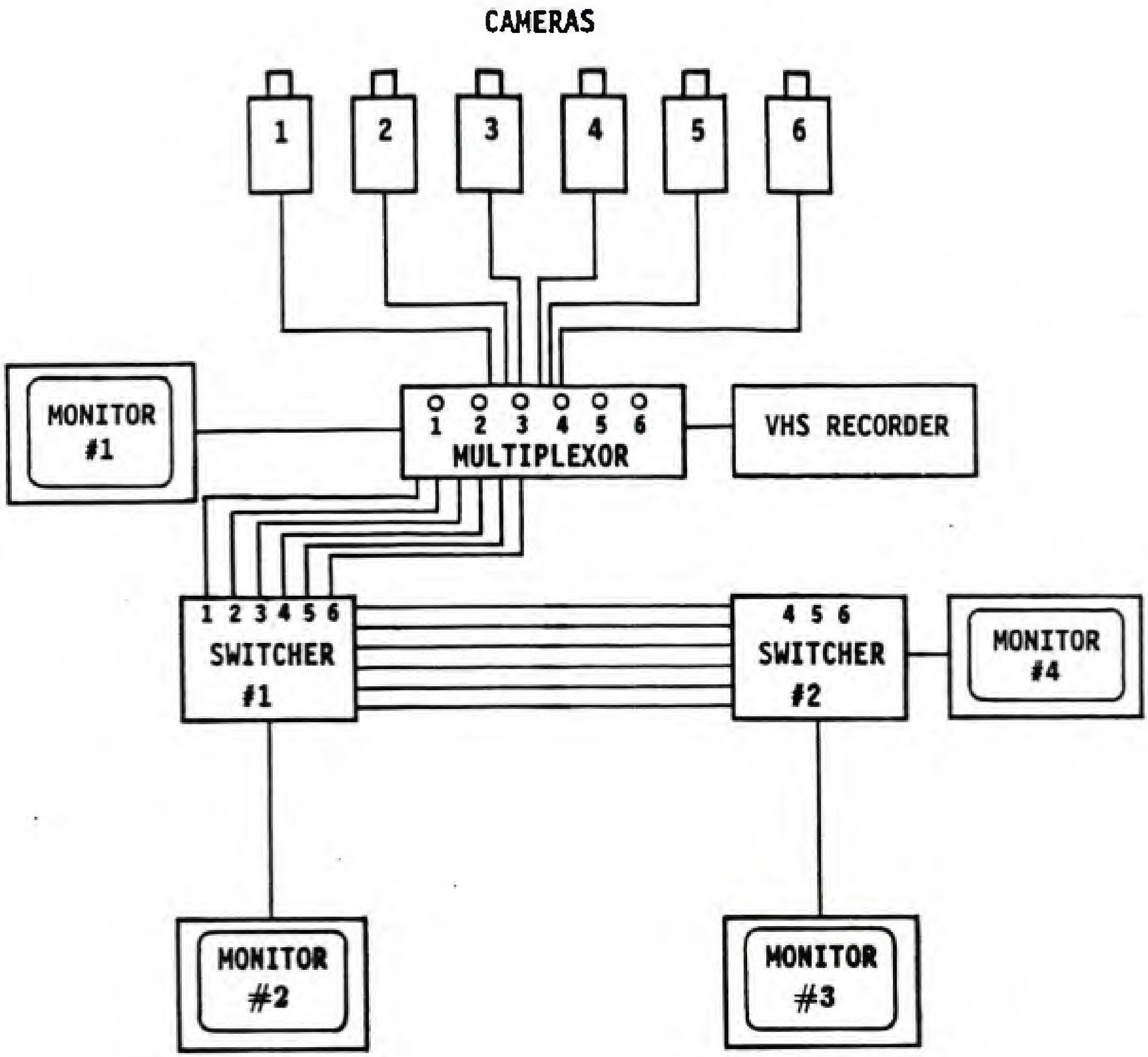
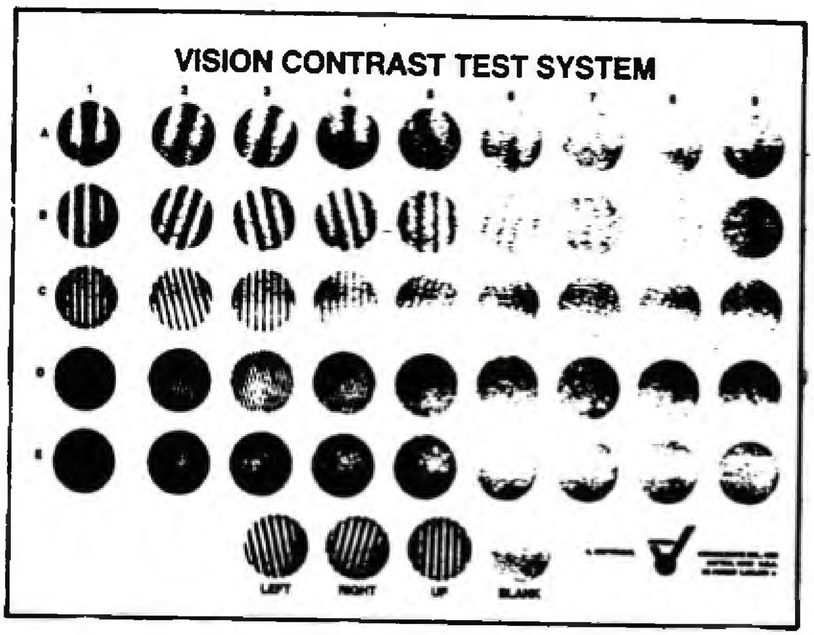


Figure 3.11. Video recording one line diagram.

VCTS®

Contrast Sensitivity Testing



Vistech Consultants, Inc.

Vision Contrast Test System

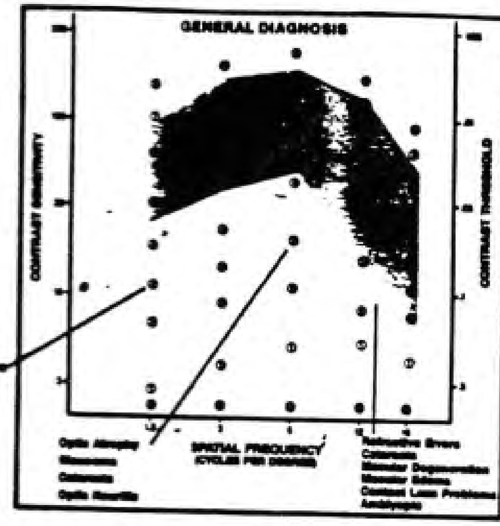
- Early Detection of Pathology
- Easily Administered by a Technician
- Functional Assessment and Documentation of Cataracts
- Objective Fit and Evaluation of Contact Lenses
- Quick, Precise Refraction

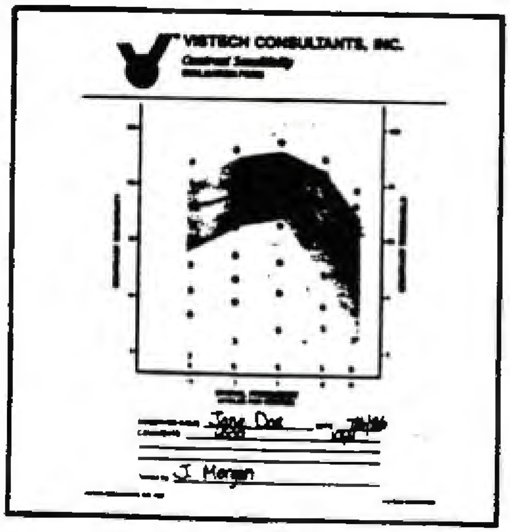
Figure 3.12. Contrast Sensitivity Testing.

Contrast sensitivity testing is the most comprehensive way to measure functional vision. Standard acuity charts test only the patient's ability to see small high contrast (black on white) objects. Our everyday world, however, is not viewed in black and white. To see a child crossing the road at dusk or track a golf ball across the sky, one must be able to resolve different size objects under lower levels of contrast (shades of grey). A simple, scientifically-proven method for measuring contrast sensitivity, the Vision Contrast Test System (VCTS®), was developed by Dr. Arthur Ginsburg.

The VCTS® near and distance charts consist of five rows of sine-wave gratings, which appear as fuzzy gray bars. Each row tests at a specific spatial frequency, measuring the observer's sensitivity to a specific object size. The low frequencies, at the top of the chart, test sensitivity to very large objects, while at the bottom of the chart the high frequencies test sensitivity to very small objects. Each test frequency begins with a high level of contrast which diminishes progressively with each succeeding patch from left to right. The gratings vary in their orientation within the patch, and may be vertical, or tilted right or left. *Sine-wave gratings are used because scientific research has shown them to be more sensitive than any other test pattern.*

Extensive scientific research documents the validity of the VCTS® in numerous areas of eye health care. The charts are highly calibrated and standardized. To establish proper illumination, a light meter is included with each system. *Standardization is essential for consistent test results in any location, ensuring accurate evaluation of patient vision for diagnosis, patient referrals, second opinions, and documentation.* The VCTS® projection slide, although nonstandardized, can be used for precise refraction, contrast sensitivity screening, and contact lens evaluation.





The Vistech Consultants, Inc. VCTS® can easily be administered by a technician in only two minutes. The observer simply reports the lowest contrast patch visible in each row and describes the orientation of the gratings. The results are recorded on a contrast sensitivity evaluation form and can be immediately compared to a population norm. Since acuity charts are just one variable (size), only a single number can be used to describe a person's vision. The VCTS® uses two variables (size and contrast) to test across the entire range of vision; therefore, the results produce a curve. If needed, this curve can be converted to a standard acuity value that relates to everyday functional vision.

Many pathological and neurological conditions affect vision in ways that cannot be measured by acuity alone. Cataract patients, for example, may complain that they are unable to see to drive, yet perform well on an acuity chart. Certain types of decreases in the contrast sensitivity curve can indicate different visual problems. For example, a loss affecting only the mid-frequency might suggest the possibility of glaucoma. The diagram above shows what type of problems may affect specific portions of the curve. A completed instruction manual is provided with the VCTS® to illustrate sample curves and aid in diagnosis.

Cataracts

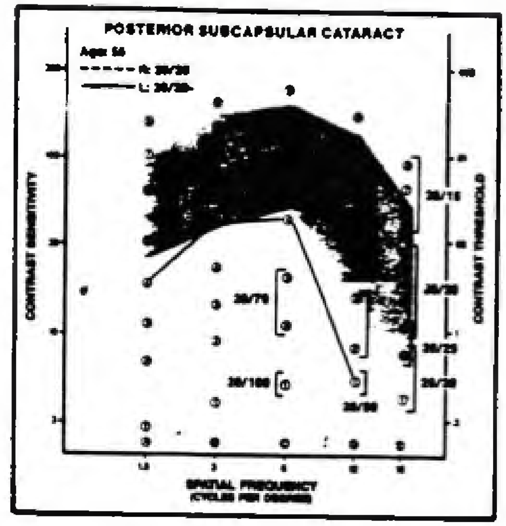
Cataracts are an increasing vision problem as the size of the older population grows. Cataracts cannot effectively be measured by present acuity tests because acuity measures optical blur, how sharply an image is in focus. Cataracts, however, do not affect

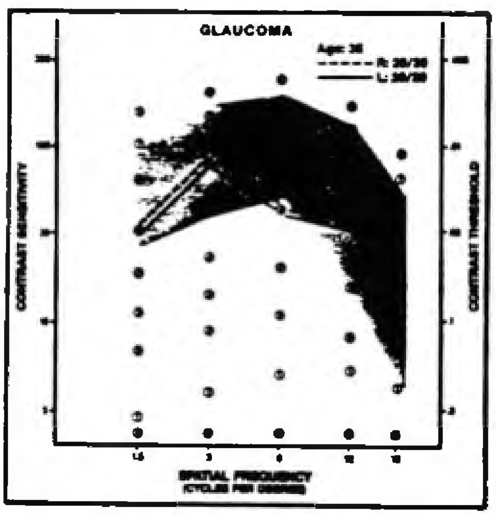
Figure 3.12. Contrast Sensitivity Testing (Con't).

blur. The scattering of light through the lens opacity reduces the contrast of images. Acuity charts use such high contrast targets that they can still be read by cataract patients, even though the letters appear "hazy" or "washed-out."

The example on the right shows the contrast sensitivity curves of a patient with a posterior subcapsular cataract in the left eye. Although the patient's standard acuity was normal (20/20), the contrast sensitivity curve for that eye falls significantly below the population norm.

By noting where the lowest point of the curve lies on the Equivalent Acuity Guide (shown superimposed on the sample graph), an equivalent acuity value can quickly be determined. In this case, the equivalent acuity of the left eye is 20/50. This means that the quality of vision experienced by the patient in that eye corresponds to that of a person reading 20/50 due to refractive error. *With the VCTS®, decisions concerning surgery can be based on a measure which more accurately relates to visual performance.*





Glaucoma

Documented research has shown contrast sensitivity to be an important screening test for early detection of glaucoma. In this example, the patient had no field loss or cupping, but depressed contrast sensitivity in the middle frequency region of the curve. The higher and lower frequencies were not affected. Glaucoma patients can show visual losses in contrast sensitivity but not in other tests and vice versa. The VCTS®, used in conjunction with standard screening tests, provides the most sensitive information possible for early detection of glaucoma.

Contact Lenses

Contact lenses can affect vision in ways that cannot be adequately measured by acuity. By evaluating contact lens performance with the VCTS®, the doctor can provide the patient with the best possible correction. In the example shown, two types of lenses both correct the patient to 20/15 standard acuity. The substantial difference in contrast sensitivity, however, clearly indicates with which lens the patient will be happier. The patient's vision with contact lenses can also be compared to a contrast sensitivity measurement taken through the phoroptor or with the patient's present glasses. This comparison quickly identifies functional losses that could lead to patient complaints. Immediate refitting saves valuable time and increases patient satisfaction.

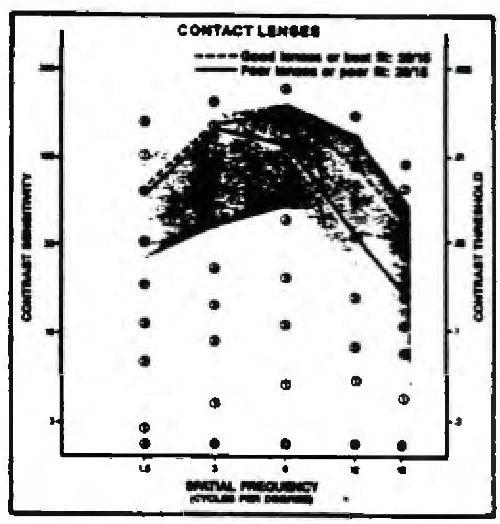
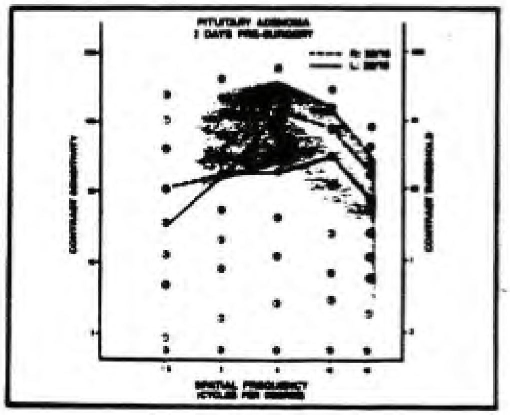


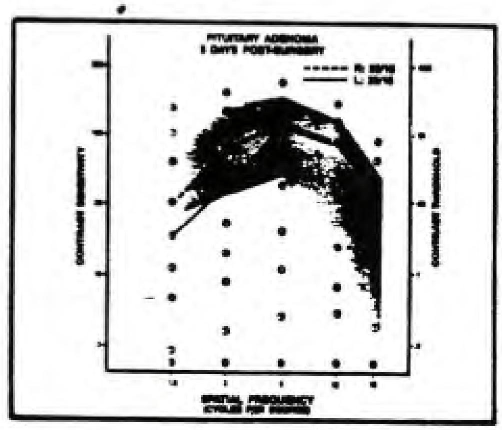
Figure 3.12. Contrast Sensitivity Testing (Con't).

Pathology

Many types of visual pathway disorders do not affect optical blur and thus cannot be detected and quantified by standard acuity charts. Examples of these types of problems include multiple sclerosis, optic nerve lesions, and tumors. An interesting example is a case involving a pituitary adenoma.

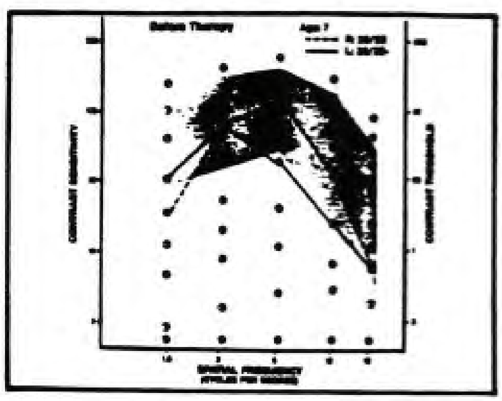
The 30 year-old patient's complaint of blurred vision in the left eye and left frontal lobe headaches had been attributed to stress by a general practitioner. An eye doctor tested the patient's Snellen acuity, color vision, central Amsler grid, and pupilary reactions and found no abnormal results. A significant loss of vision in the left eye, however, was discovered through contrast sensitivity testing. The doctor's suspicion of a tumor was later confirmed. Five days following surgery the patient was retested, with the results showing a substantial improvement in contrast sensitivity.





Amblyopia

The VCTS® is a very effective device for measuring the vision of amblyopia patients. Pre-school children can easily indicate the direction of the gratings regardless of their reading ability. Contrast sensitivity is a sensitive tool for detecting suppression even in patients with normal or near normal acuity. Vision therapists use the VCTS® to determine training procedures and track recovery. The curves also provide an excellent aid for illustrating progress to the parents. They can be shown the significant difference between the curves of each eye and follow the child's progress as vision improves and the curves become consistent.



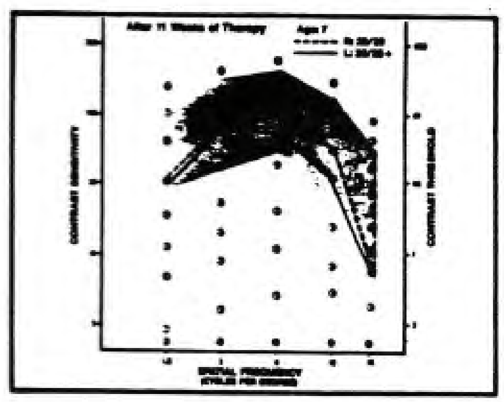


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Figure 3.12. Contrast Sensitivity Testing (Con't).

It should be noted that the group's numbers and physical limitations combined at various times into a quite uncontrolled behavior pattern. The plan to assign personnel on the basis of eyesight was cancelled at the outset because so many of the assigned personnel were covered by limited duty restrictions. The test plan called for 24 personnel in order to operate with 20 after examination and no shows. The test needed 19 personnel to be fully staffed and could hobble along with as few as 16. Frequently it was necessary to operate with 10 or 12 personnel, with only 8 of the needed 16 actually performing test tasks. In such an environment, if someone who was supposed to wear glasses didn't, it was never noted or corrected.

Organization

The assigned personnel were organized into pairs of intruders and observers as shown in Figure 3.13. Generally able bodied personnel were assigned to the intrusion tasks instead of those with eyesight difficulties. An intruder team leader tried diligently to keep the intrusions on schedule according to the second by second script. An observer team leader was assigned to keep the observers in the van diligent, but this member was rarely to be found at the test site. A communications coordinator was assigned to keep observers and all intruders keyed to the same point in the script, using hand-held radios for communications. A master chief was in overall charge of the personnel, and determined assignments.

Pier Intruders

Pier intruders were dressed in dark blue coveralls and stationed in pairs at blinds generally to the left side of the pier at three locations along the pier.

Range A was roughly 600 feet down the pier (halfway to the end). Range B was roughly three-fourths of the distance to the end of the pier (900 feet from the head). Range C was near the end of the pier, nominally 1200 feet from the pier head. The blinds were made of structural elements that were close to these desired locations. Range A used a pair of trash containers placed to hide the intruder team unless they were involved in an intrusion. Range B used a polyethylene screen attached to a transformer railing. Range C merely used the transformer housing itself as a shield from view from the head of the pier.

Each intruder pair consisted of an intruder trained to run at 15 feet per second, and roll or crawl at 1.5 feet per second, as well as a monitor to read the script and cue the intruder actions. The intruder monitor was provided with a detailed script and clipboard, flashlight, hand held radio, and a Casio digital watch/stopwatch. The intruder wore elbow and kneepads under 0.07 reflectivity coveralls.

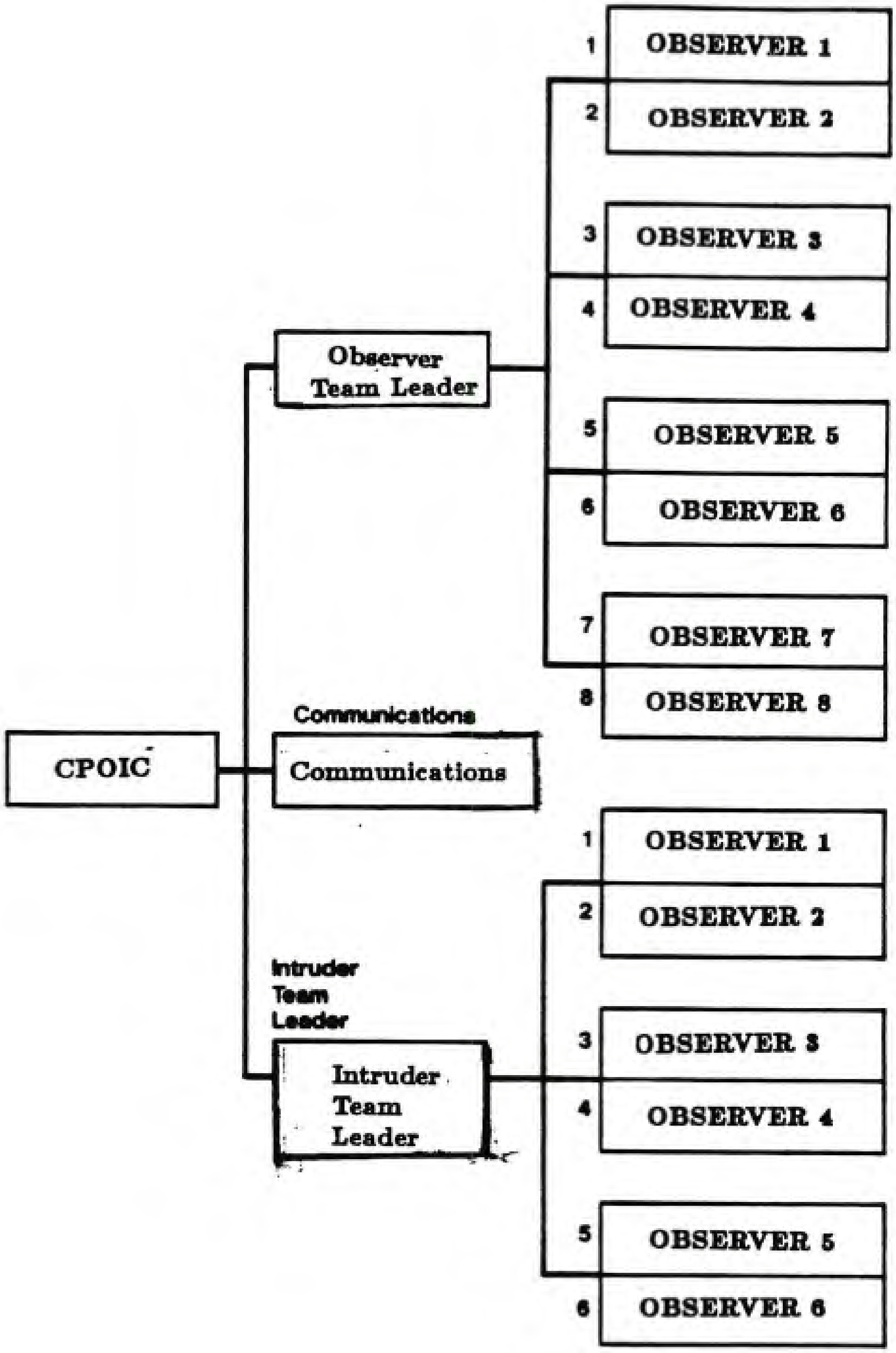

Figure 3.13. Organizational chart.

Intruder monitors performed at all levels of competence, from well to not at all. In some cases insufficient numbers of personnel caused intruders and monitors to do double duty. In other cases, monitors miscued the intruders or lost their place in the script and the intrusion was done at the wrong time or not at all. Infrequently, the monitors wrote on the script, as directed, the actual time of completion of the intrusion.

Pier Observers

Up to 10 personnel performed observations of the intrusions. The observers were teamed into pairs with one performing as monitor and the other observing. The observer was tasked to cue the observer when to look, time the answer, and record the result on the data sheet. The observer was tasked to look for an intrusion; call out the action as a run, roll, crawl stand, or false alarm; and identify the range as A, B, or C. UP to four teams were located in the van near the head of the pier using the four monitors. Each team was separated from visual contact with the others by equipment racks and polyethylene curtains. Each observer was acoustically isolated from others by a headphone radio. A fifth observer team was located at the head of the pier for direct observation instead of using CCTV aids.

Camera 1 was located at the top of the lighting mast near the pier head, looking all the way down the pier from 600 feet to 1200 feet distant. Camera 2 was located essentially directly below camera 1, looking all the way down the pier at eye level in order to directly compare with the direct eyeball observation. Camera 3 was located near the top of the mid pier mast looking outward down the pier from at ranges B and C, 900 and 1200 feet. Camera 5 looked back toward shore from the 75 foot height of the ranging tower near the end of the pier, viewing range B at 900 feet and range A at 600 feet.

The observer team leader was assigned the task of keeping interactions between personnel in the van to a minimum. This was to include talking, horsing around, sleeping, etc. The team leader did none of these and the resultant interaction and inattentiveness may affect the results. Also, most of the time a lack of personnel resulted in observers recording their own results without the assistance of a monitor. This certainly offered the opportunity for cheating, since the correct results on the scoresheet had to be covered up to prevent seeing them.

Water Intruders

Water intrusion tests were performed by trainees from NAVSPECWARCEN using two teams in inflatable zodiacs with outboard motors. About six personnel were carried in each of the two boats. All wore wet suits of nearly black foam. The covering of the outboard motor was noted as imperfect as it allowed some white paint to be seen from some angles. The boats were used to perform fast, slow, stop movements across the water test areas between Pier 4 and 5 as was shown in Figure 3.7. Fast was around 5 knots speed, while slow was about 0.5 knots. The boats were also used to deploy swimmers that swam similar routes, along the pier and across the pier orientation.

The water intrusions were performed almost flawlessly in spite of the wet and cold all night conditions.

Water Observers

Up to seven observer teams from the NAVSTA personnel recorded the water intrusions. Three of the teams watched the re-aimed Camera 1, Camera 2, Ca,era 3 and Camera 5 views of the water. A new Camera 6 was placed at the outboard bridge of the moored ship on Pier 5 directly across from the water intrusion test area. Three direct eyeball observation teams were used. One was located as before at the pierhead next to Camera 2. Another was placed on the moored ship just below the new Camera 6. A final team was placed aboard a NAVSTA police boat anchored around 300 feet. out in the channel between Piers 4 and 5.

As before, observer teams were planned to consist of observer and monitor with the same duties previously documented.

3.5 TEST OPERATIONS

Active security test operations were conducted in a two week period from November 29 to December 8, 1988. Weather was close to ideal during the entire period, with clear skies and imperceptible wind.

3.5.1 Training and Set Up

The week of September 26 to 30, 1089 was devoted to mustering the NAVSTA personnel, re-configuring the CCTV van, acquiring miscellaneous equipment, and training the personnel by means of a rehearsal. The rehearsal proceeded quite smoothly on September 28 and 29. The light meter was used to measure the pier surface reflectivity, lighting illuminances, and coverall reflectivity. All cameras were aimed for viewing the proper locations.

During this period the lighting system experiences increasing levels of malfunctions. These lighting difficulties began to affect the operation of certain cameras. Some electrical problem seemed to be deteriorating. On Sunday, October 2, the NCEL Test Director cancelled the planned operations pending reliable lighting. The delay in operations continued for 8 weeks before the lights were pronounced operational. On November 28, test operations initiated.

3.5.2 November 28

Four ships were moored at Pier 5. Two FFs were rafted on the outer half toward Pier 4. The AD was on the inner half toward Pier 4. Another ship was on the outer half toward Pier 6.

At 1310, the planned start of pier intrusions, only 12 personnel had arrived and continuing electrical problems caused Camera 1 to be inoperative. At 1400 intrusions were started in order to obtain as much day data as possible. At 1506 the lighting contractor arrived to fix pole 1 and shut down all power to all cameras. The day tests are aborted.

By 1800, all repairs are complete and the test of night full power lighting from 100 foot height begins as planned. Tests are completed as planned by 2200.

3.5.3 November 29

The AD has departed and one of the FFs has moved to the inner half of the pier from the raft to replace it.

At 1800 testing of the low power configuration at 100 foot height proceeds. At 2300 all pier lighting is turned off to observe intrusions in the dark as is the present Navy practice. It is noted to be approximately half moon.

3.5.4 November 30

No change to the mooring configuration has occurred. The trash cans used as a blind for range A are missing and all intrusions are run from right to left to take advantage of other cans.

At 1800 testing with the lights at full power and 50 foot height begins. Camera 3 is now adjusted to observe ranges B and C from a height of 45 feet. At 2300 testing at low power 50 feet height proceeds.

3.5.5 December 1

During the day all lights are re-aimed to provide a "glare lighting" scheme for the pier and the water test area. The luminaires are aimed generally at flat angles long distances from their poles in order to achieve more uniform lighting. One lamp from each of poles 2 and 3 are aimed at range B. Four lamps from pole 2 are aimed at range C. Two lamps from each of 1 and 3 are aimed at range A. All the rest are aimed at Pier 4 (water) at a 10 degree down angle.

At 1300 the day intrusion testing is performed while light re-aiming is in progress. At 1800, night pier intrusion testing is begun using the re-aimed glare lighting. At 1820 the LANG arrives and takes 6 to 10 minutes to get lines on the dock. By 1837 the brow is in place and the crane is departing Pier 5. Lighting measurements indicate a very uniform 2 foot candles at high power. At 1920 power is reduced to low providing a uniform 1 foot candles for the rest of the test. At 2200 pier intrusion testing is complete.

3.5.6 December 4

At 1800 water intrusion testing begins with no moon and clear cold skies. Lights are operated at full power and 100 feet height. Light illuminance is measured on two paths on each side of the test zone parallel to Pier 4 and proves to be impressively uniform at 0.20 to 0.64 foot-candles in the horizontal plane. Measurement in the vertical plane show 1.2 to 2.5 footcandles. The intrusion zodiacs are effectively black but the outboards are showing some white around the cover. The cover is only an olive drab jacket. Intruders are cautioned to keep the outboards from being visible.

From 1800 to 2000 camera 6 is being installed on the FF moored on the outer half of Pier 5 facing Pier 4. At 2100 the new camera is operational. Observation configuration:

Monitor 2 - Camera 1 Monitor 3 - Camera 2 (until 2000) Monitor 3 - Camera 6 (after 2100) Monitor 4 - Camera 5 Pier at Camera 2 Ship at Camera 6 Patrol Boat 100 yards out in channel

At 0240, Pole 3 (and maybe pole 2) went from high to low power. At 0250, the power came back up again. This malfunction was never explained.

There is significant difficulty getting the cameras aligned with the intrusion zone perfectly. This results in intrusions sometimes missing the field of view or some very late "alarms."

3.5.7 December 5

Water tests continue with the lighting turned off. Light levels on the water are again quite uniform at 0.001 to 0.010.

3.5.8 December 6

Cameras 2 and 6 re-aimed better to intersect with the "stop boat" intrusion. Lights operated at full power and 50 feet height. Light levels of 0.030 to 0.27 except a hot spot of 0.6 near end of Pier 4.

3.5.9 December 7

This day is a lay day giving the personnel rest to perform day water intrusions on December 8. At 1435 the US Rentz (FF 46) arrives. The crane arrived 25 minutes earlier. Lines are taut by 1443 when brow placement begins. At 1444 lines have been doubled. By 1453 brow is in place.

3.5.10 December 8

Final water intrusions begin scheduled to begin at 0730. Tests are delayed by ship traffic and by intermittent power problems caused by high tide. By 1018 team is only to event 24 and by 1510 to event 58.

3.5.11 December 9 through January 15

December 9 all cameras were re-aimed to record pier operations and safety data.

All lights were re-aimed to there original spots for pier low glare illumination. Base personnel were trained in reloading the video recorder and the system turned on to operate without significant attention.

Until NESEA personnel arrived on January 16 to disassemble the CCTV instrumentation, passive recording continued. On January 16 and 17 the tapes were reviewed to record data and no night mooring operations were found.

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SECTION 4

QUANTITATIVE DATA REDUCTION AND RESULTS

4.1 TEST CONDITIONS

The description of the actual field test conditions is central to understanding the conclusions and limitations on interpreting data. This test program involved the complexities of a 1200 foot long operational Navy pier, a new 13 kw HPS lighting system on 100 foot high masts, a 6 camera CCTV instrumentation system with fully multiplexed video recording, a team of 21 Navy personnel to perform intrusions and observe, and a pair of trainee seal teams for water operations. Nearly 2000 intrusions were recorded from as many as 5 different observation points, providing over 8000 data points.

4.1.1 Photometric Instrumentation

A Tektronics J16 digital photometer was leased from Leasametrics for this project. This instrument operates through several alternate luminance probes which are matched to the photopic response of the human eye. Three probes were also leased to support this activity. A J-6501 illuminance probe was used which has a hemispherical receptor to measure incident footcandles from all source directions. A J-6503 illuminance probe was used to measure the incident light from a single source by means of a highly directional 1 degree acceptance beam. A J-6511 luminance probe was used to measure the background luminance in foot-Lamberts for a moderately narrow 5 degree beam.

4.1.2 Surface Reflectivities

Using the luminance probe, the following luminance were measured in daylight, and reflectivities determined relative to the white coveralls. Other sources show asphalt reflectivity from 10 to 10 percent and concrete from 10 to 30 percent.

Surface	Foot Lamberts	Reflectivity
White coveralls	8450	1.0
Blue coveralls	160	0.019
Asphalt	540	0.064
Clean concrete	1520	0.18
Concrete	1040	0.12
Dirty concrete	540	0.06

4.1.3 Pier Reflectivities

Using the hemispherical illuminance probe, rationing the down readings to the up readings at dusk and under the lights, the surface reflectance readings were confirmed many times. The pier surface exhibits reflectance from 0.09 to 0.33, with most of the readings between 0.1 and 0.15. Figure 4.1 provides a graph of measured

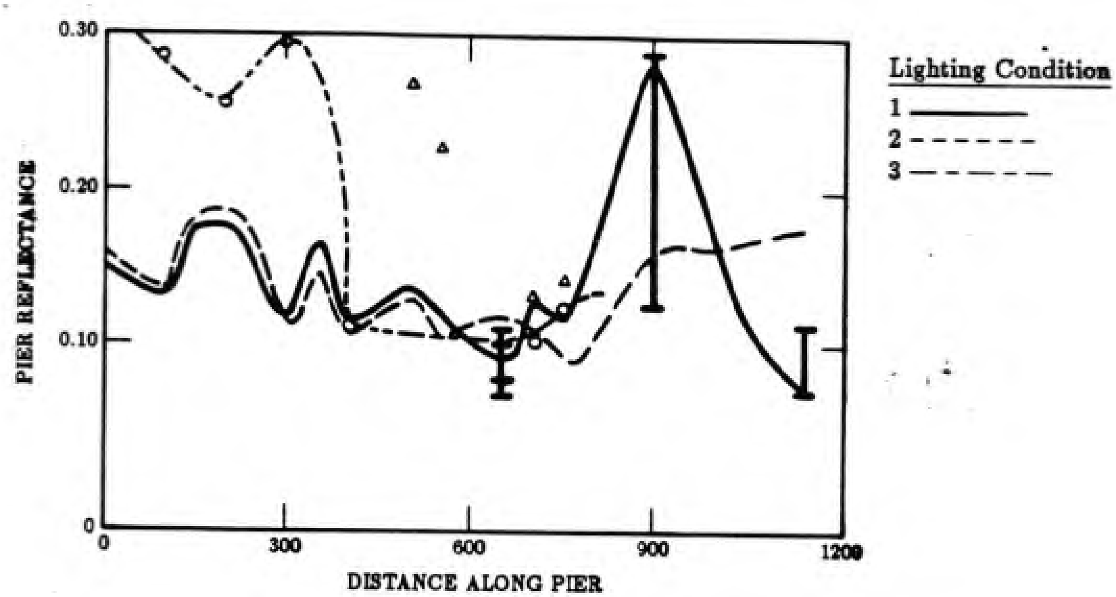

Figure 4.1. Measured pier reflectance.

reflectivity along the pier as derived from a ratio of the hemispherical foot-candle probe measuring upward and measuring downward.

4.2 INTRUDER REFLECTIVITY

Intruders on the pier surface were dressed in dark blue coveralls that measured (160 ftL), 0.02 of the value of luminance from white coveralls (8450 ftL).

4.3 LIGHTING ILLUMINANCES

The tested lighting system was originally installed and aimed by the lighting contractor. Aiming of the luminaires was intended to minimize spilled energy and glare, while obtaining fairly uniform lighting. These contradictory requirements caused significant hot spots, with intruder range C being consistently brighter than the others. A second glare lighting setup used 12 of the 32 luminaires aimed 300 to 600 feet away from the poles to provide quite uniform pier lighting. The other 20 luminaires were aimed toward Pier 4 to provide fairly uniform lighting over the water surface simultaneously. Typical lighting levels at the intruder ranges (A is 600 feet from pierhead, B is 900 feet from pierhead, and C is 1200 feet from pierhead), vary from 0.005 to 36 foot candles on the horizontal plane of the pier surface, as indicated in the following Table 4.1.* Figure 4.2 is a plot of this horizontal lighting data. Table 4.2 and Figure 4.3 show the same test lighting conditions corrected to the vertical plane.

Figure 4.4 shows the variation of the lighting intensity along the pier for full power lighting at 100 foot mast height. Figure 4.5 shows the lighting variation across the pier at range C on two separate measurements with full power lighting at 100 foot mast height. Figure 4.6 shows the measured illuminances at the three intrusion ranges under 100 feet-high power lighting.

It is important to note that the pier surface, whether a result of the natural concrete or the oil and tire residue, exhibited significant directional glint. This created glare which may have been helpful at times in detecting night pier intrusions, but was certainly detrimental at times just before sunset to cameras and observers looking into the glare.

*The dashed and broken lines in Figure 4.4 are illuminance levels on the vertical plane. Both of these lines are *calculated* from the mid pier to the end of the pier. They were *not* calculated from the pier head to the mid pier. The broken line is for the light seen by Camera 5 located at the end of the pier. The dashed line is for Camera's # 1 and 2 located at the pierhead and Camera 3 at mid pier. As one approaches the end of the pier the vertical illuminance as seen by Camera's 1, 2 and 3 goes to a level of about 1 FC while that seen by Camera 5 goes to about 10 FC.

Table 4.1. Summary of Pier Surface Lighting Illuminance.

LIGHTING CONDITION	INTRUDER RANGE		
	A	B	C
11/28-100' HIGH POWER	3.8	1.0	36.
11/29-100' LOW POWER	2.0	0.33	10.
11/29 DARK	0.005	0.04	0.2
11/30-50' HIGH POWER	15.	0.4	36.
11/30-50' LOW POWER	4.5	0.1	8.1
12/1-100' GLARE HIGH POWER	1.8	1.8	2.4
12/1-100' GLARE LOW POWER	1.2	1.0	1.8

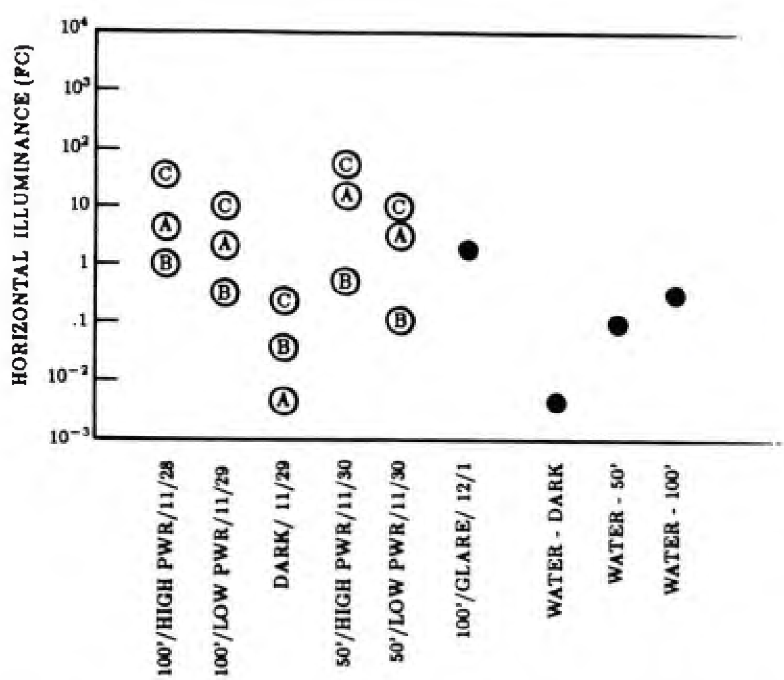

Figure 4.2. Lighting illuminances at intrusion ranges.

Table 4.2. Summary of Pier Lighting in Vertical Plane.

LIGHTING CONDITION	INTRUDER RANGE SEEN FROM SHORE			INTRUDER RANGE SEEN FROM CAMERA 5	
	A	B	C	A	B
11/28-100' HIGH POWER	2.3	1.5	0.4	0.2	1.5
11/29-100' LOW POWER	1.2	0.5	0.1	0.05	0.5
11/29 DARK	0.005	0.04	0.2	0.005	0.04
11/30-50' HIGH POWER	1.8	1.2	0.3	0.15	1.2
11/30-50' LOW POWER	5.4	0.3	0.08	0.04	0.3
12/1-100' GLARE HIGH POWER	5.4	2.7	14.	5.4	2.7
12/1-100' GLARE LOW POWER	3.6	1.5	10.8	3.6	1.5

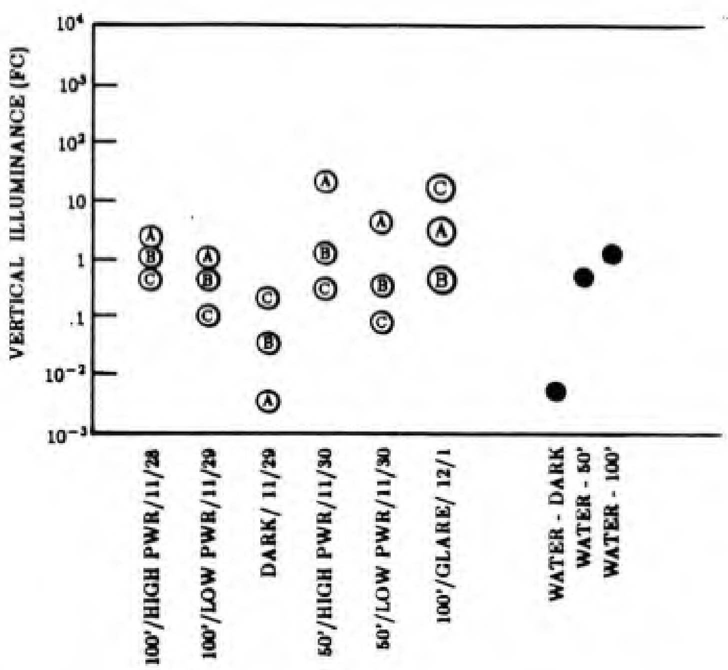

Figure 4.3. Lighting Illuminance in Vertical Plane.

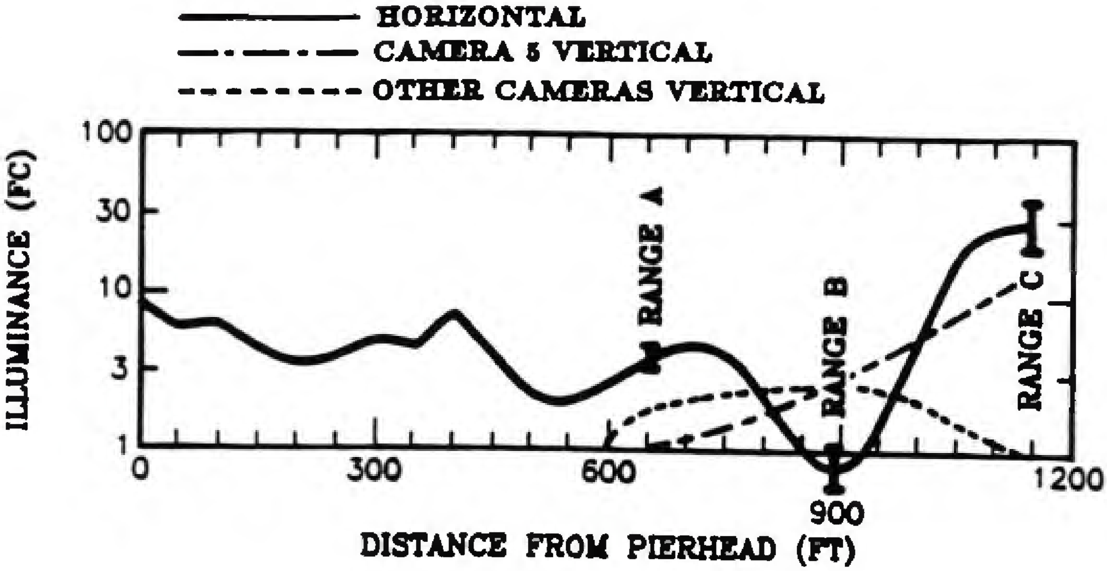

Figure 4.4. Illuminance with 100 foot, high-power Lighting.

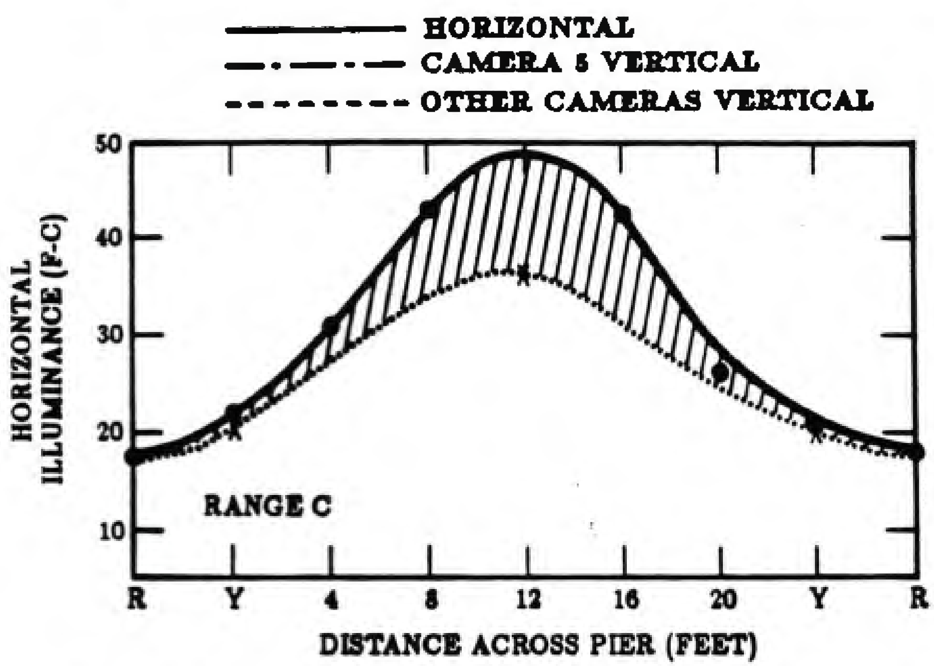

Figure 4.5. Repeatability of illuminance Measurement.

Detection of pier intrusions at night may not be a simple relationship between contrast ratios and background luminance at the test ranges. This is because hot spots such as that usually present at range C can backlight actions at range A and B. Also reflected light off the pier surface can serve to provide greater illuminance on the target than would otherwise be expected. Pier illuminance data provides an important part of the information, but is by no means a complete story. Figures 4.7 through 4.11 show the illuminance along the pier surface for each lighting condition tested. Curves are coded as in Figure 4.4

4.4 DATA RECORDING AND REDUCTION

This section explains precisely how the field data recording took place and how such data were reduced to provide the conclusions.

4.4.1 Scripts

In order to control the actions of around 20 intruder and observer personnel, computer randomized scripts were created. Figure 4.12 shows the first page of one of the three alternate pier intrusion scripts. It defines the event number, which of the three intrusion ranges is host to the event, the threat tactic to be simulated, the nominal start time (one per minute), the randomized delay after the minute so the observer doesn't expect immediate action, the desired finish time, and the exact personnel to be involved. Three different sequences of the events is available to assure that observers don't acclimate to a particular sequence. After the first 107 events a 20 minute break was scheduled and after the full 214 events, a dinner hour was provided. After dinner another 214 event script was performed. This system worked quite well at minimizing the necessity of continuous queuing communications and letting non-performers relax between events. Infrequent radio checks were sufficient to keep all parties on the proper event. Events consisted of run, crawl, roll, stand, and false alarm. Ranges, measured from the head of the pier were nominally: A, 600 feet; B, 900 feet; C, 1200 feet.

Figure 4.13 shows the analogous script for the water intrusions. These intrusions were performed every 6 minutes due to the larger distances over which the intrusions had to be executed. Seventy water intrusions were scheduled each evening. Events were swim, slow boat, fast boat, stop boat, and false alarm. Water intrusions were performed both parallel to the piers (along), and perpendicular to the piers (across).

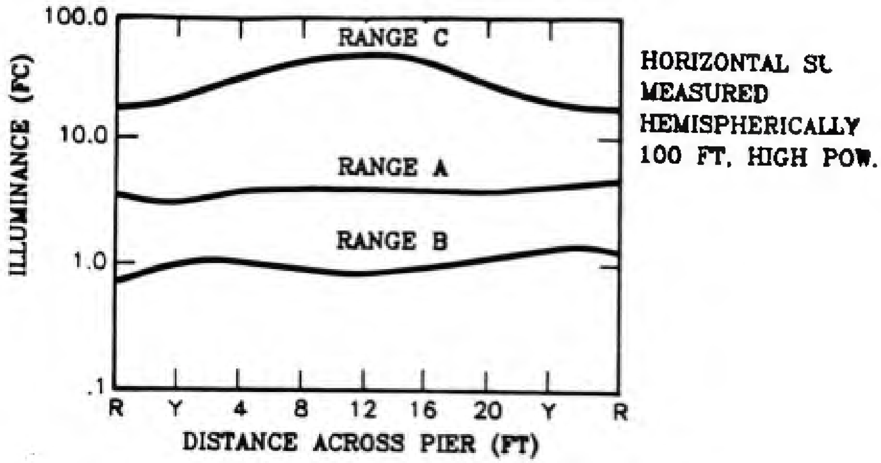

Figure 4.6. **Illuminance across pier.**

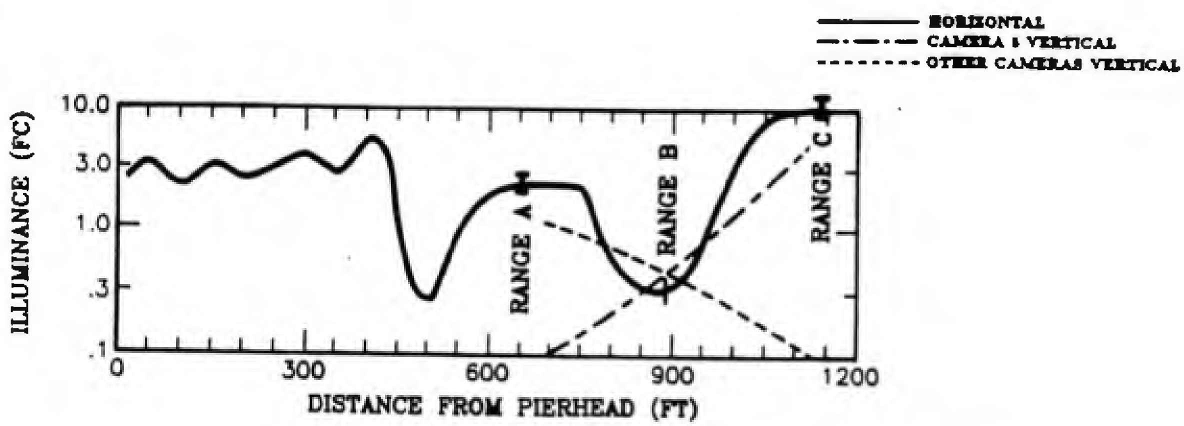

Figure 4.7. **Illuminance with 100 foot, low-power.**

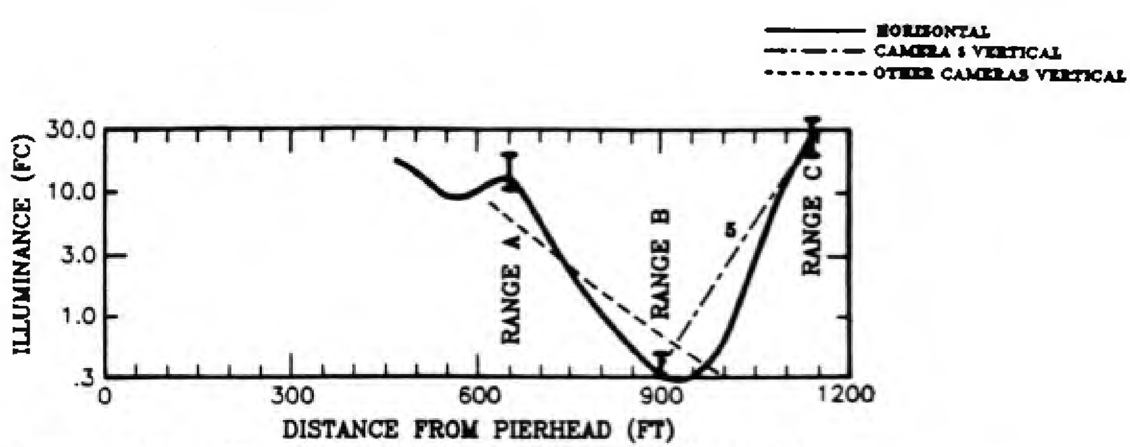

Figure 4.8. **Illuminance with 50 foot, high-power.**

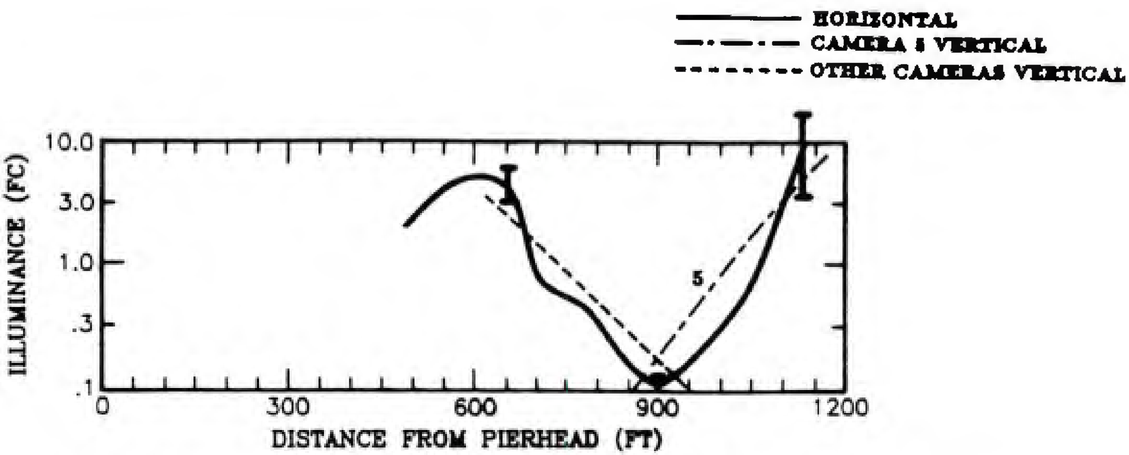

Figure 4.9. Illuminance with 50 foot, low-power.

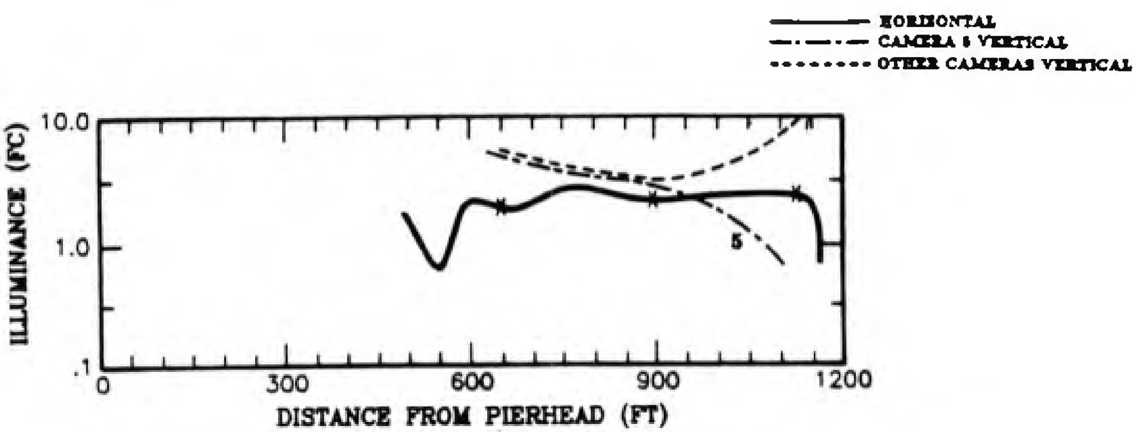

Figure 4.10. Illuminance with 100 foot, high-power glare.

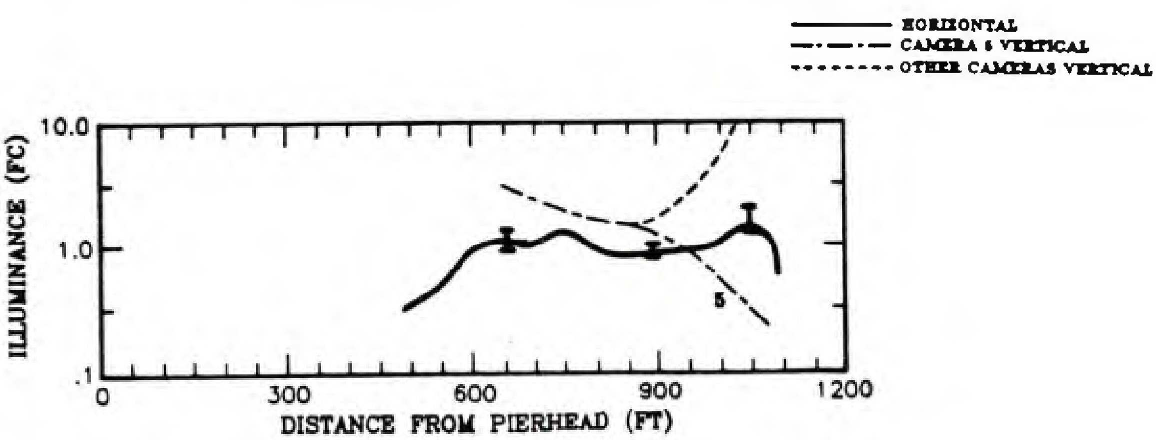

Figure 4.11. Illuminance with 100 foot, low-power, glare.

INTRUSION SCRIPT   I1

DATE: OCT. ____, 1988   LIGHTING: ____________

LOCATION: ____________

EVENT	RANGE/ACTION	START	DELAY	FINISH	INTRUDER	MONITOR
1	A -- RUN	0100:00	6 SEC	0100:08	1	2
2	B -- RUN	0101:00	6 SEC	0101:08	3	4
3	A -- STAND	0102:00	0 SEC	0102:40	1	2
4	C -- ROLL	0103:00	8 SEC	0103:28	5	6
5	B -- RUN	0104:00	6 SEC	0104:08	3	4
6	B -- STAND	0105:00	0 SEC	0105:40	3	4
7	C -- CRAWL	0106:00	10 SEC	0106:30	5	6
8	C -- CRAWL	0107:00	10 SEC	0107:30	5	6
9	A -- RUN	0108:00	0 SEC	0108:02	1	2
10	B -- RUN	0109:00	0 SEC	0109:02	3	4
11	C -- RUN	0110:00	8 SEC	0110:10	5	6
12	B -- STAND	0111:00	0 SEC	0111:40	3	4
13	B -- CRAWL	0112:00	8 SEC	0112:28	3	4
14	C -- ROLL	0113:00	4 SEC	0113:24	5	6
15	B -- ROLL	0114:00	6 SEC	0114:26	3	4
16	C -- CRAWL	0115:00	6 SEC	0115:26	5	6

Figure 4.12. Pier intrusion script.

WATER INTRUSION SCRIPT I1

DATE: OCT. ____, 1988 LIGHTING: ____________

LOCATION: ____________

EVENT	TEAM	ACTION (DIRECTION)	START	DELAY	FINISH
1	A	SLOW (ALONG)	2000:00	12 SEC	2004:12
2	B	SWIM (ALONG)	2006:00	0 SEC	2010:00
3	A	SLOW (ACROSS)	2012:00	12 SEC	2016:12
4	B	SWIM (ACROSS)	2018:00	24 SEC	2022:24
5	A	FALSE ALARM	2024:00	0 SEC	2028:00
6	B	STOP BOAT	2030:00	0 SEC	2034:00
7	A	SWIM (ALONG)	2036:00	36 SEC	2040:36
8	B	SLOW (ACROSS)	2042:00	12 SEC	2046:12
9	A	SLOW (ALONG)	2048:00	24 SEC	2052:24
10	B	SWIM (ALONG)	2054:00	0 SEC	2058:00
11	A	SLOW (ACROSS)	2100:00	0 SEC	2104:00
12	B	SLOW (ALONG)	2106:00	12 SEC	2110:12
13	A	SWIM (ALONG)	2112:00	36 SEC	2116:36
14	B	SLOW (ALONG)	2118:00	60 SEC	2123:00
15	A	SWIM (ALONG)	2124:00	48 SEC	2128:48
16	B	SLOW (ALONG)	2130:00	60 SEC	2135:00

Figure 4.13. Water intrusion script.

4.4.2 Recording Forms

Figure 4.14 shows the properly complete intrusion script for Range C with the deviations in completion time from the script identified. This degree of compliance with instructions was rarely in evidence. Figures 4.15 and 4.16 show the observer results forms for the same intrusions witnessed from two different video monitors. Note that the identity of the observer and of the observer monitor (data recorder) is the same and that the handwriting of these identities is the same, because it was written by the authors after analysis of handwriting. Note from Figure 4.15 that Davey has filled in the fact that traffic on the pier has obscured the event, signified by "TF." Also note that question marks have been entered in certain events. Bona, on the other hand, has merely drawn a line through any event that he has not observed action. It is left to the reviewer to determine if the reason was traffic interference or an error. Both observers have properly written the seconds at which the observance was made, although this was by no means a common adherence to directions. Both of these records were generated by one person doing both jobs and therefore subject to the possibility that the event answers were not covered up during the test. Such situations depended upon individual honesty in situations where too few personnel showed up to work.

4.4.3 Grading Observation Errors

Referring again to Figures 4.15 and 4.16, we now direct attention to the right margin of the results form. The events with the question marks were determined to be intrusions that were not performed and scored as "N," nonevents. These are subtracted from the event list as if they were not even planned. Those with traffic obscuring the event, whether noted by the observer or later determined to be the excuse for unrecorded information, are scored as "T," traffic. Events that are reported incorrectly, calling for the wrong intrusion tactic, are scored as an "X," error. In situations where the observer reports the correct tactic but the wrong range, the event is scored "R," range error and receives half credit. Figure 4.17 shows a water intrusion data sheet of grading. Thirty-nine data sets (8346 events) were recorded and scored for the pier surface intrusion security tests using various lighting scenarios. Twenty-four data sets (1680 events) were recorded and scored for the water security tests.

EXAMPLE OF FIELD COMPLETED DATA SHEET

INTRUSION SCRIPT

I1

DATE: ~~OCT.~~ DEC 1, 1988

LIGHTING: DAY

LOCATION: C

EVENT	RANGE/ACTION	START	DELAY	FINISH	INTRUDER	MONITOR
1	A -- RUN	0100:00	6 SEC	0100:08	1	2
2	B -- RUN	0101:00	6 SEC	0101:08	3	4
3	A -- STAND	0102:00	0 SEC	0102:40	1	2
4	C -- ROLL	0103:00	8 SEC	0103:28	5; 25	6
5	B -- RUN	0104:00	6 SEC	0104:08	3	4
6	B -- STAND	0105:00	0 SEC	0105:40	3	4
7	C -- CRAWL	0106:00	10 SEC	0106:30	5; 30	6
8	C -- CRAWL	0107:00	10 SEC	0107:30	5; 32	6
9	A -- RUN	0108:00	0 SEC	0108:02	1	2
10	B -- RUN	0109:00	0 SEC	0109:02	3	4
11	C -- RUN	0110:00	8 SEC	0110:10	5; 11	6
12	B -- STAND	0111:00	0 SEC	0111:40	3	4
13	B -- CRAWL	0112:00	8 SEC	0112:28	3	4
14	C -- ROLL	0113:00	4 SEC	0113:24	5; 19	6
15	B -- ROLL	0114:00	6 SEC	0114:26	3	4
16	C -- CRAWL	0115:00	6 SEC	0115:26	5; 25	6

Figure 4.14. Annotated pier intrusion script.

EXAMPLE OF FIELD COMPLETED DATA SHEET

OBSERVER RESULTS

01

DATE: ~~OCT.~~ DEC. 1, 1988

LIGHTING: DAY

OBSERVER: DAVEY

LOCATION: S4/C5

MONITOR: DAVEY

EVENT	RANGE/ACTION	START	RANGE/ACTION REPORTED	TIME DETECTED	
1	A -- RUN	0100:00	TF		T
2	B -- RUN	0101:00	TF		T
3	A -- STAND	0102:00	TF		T
4	C -- ROLL	0103:00	?		N
5	B -- RUN	0104:00	TF		T
6	B -- STAND	0105:00	TF		T
7	C -- CRAWL	0106:00	?		N
8	C -- CRAWL	0107:00	?		N
9	A -- RUN	0108:00	A RUN	01	
10	B -- RUN	0109:00	TF		T
11	C -- RUN	0110:00	?		N
12	B -- STAND	0111:00	TF		T
13	B -- CRAWL	0112:00	TF		T
14	C -- ROLL	0113:00	?		N
15	B -- ROLL	0114:00	B ROLL	12	
16	C -- CRAWL	0115:00	?		N

Figure 4.15. Observer data recording form for (Camera 5, Monitor Station 4.

EXAMPLE OF FIELD COMPLETED DATA SHEET

OBSERVER RESULTS — 01

DATE: ~~OCT.~~ Dec 1, 1988 — LIGHTING: DAY

OBSERVER: Bona — LOCATION: 52/C1

MONITOR: Bena

EVENT	RANGE/ACTION	START	RANGE/ACTION REPORTED	TIME DETECTED	
1	A -- RUN	0100:00	—		T
2	B -- RUN	0101:00	—		T
3	A -- STAND	0102:00	—		T
4	C -- ROLL	0103:00	C ROLL	20	
5	B -- RUN	0104:00	—		T
6	B -- STAND	0105:00	—		T
7	C -- CRAWL	0106:00	—		T
8	C -- CRAWL	0107:00	C CRAWL	7	
9	A -- RUN	0108:00	—		X
10	B -- RUN	0109:00	B STAND	19	
11	C -- RUN	0110:00	C RUN	14	
12	B -- STAND	0111:00	—	—	X
13	B -- CRAWL	0112:00	C ROLL	10	X
14	C -- ROLL	0113:00	—	—	X
15	B -- ROLL	0114:00	B ROLL	18	
16	C -- CRAWL	0115:00	C CRAWL	13	

Figure 4.16. Observer data recording form for (Camera 1, Monitor Station 2).

EXAMPLE OF FIELD COMPLETED DATA SHEET

WATER OBSERVER RESULTS 01

DATE: DEC. 8, 1988 LIGHTING: DAY

OBSERVER: MANZANARES LOCATION: M2/C1

MONITOR: ROBERTSON

EVENT	ACTION (DIRECTION)	START	ACTION REPORTED	TIME DETECTED
1	SLOW (ALONG)	1800:00	—	—
2	SWIM (ALONG)	1806:00	—	—
3	SLOW (ACROSS)	1812:00	—	—
4	SWIM (ACROSS)	1818:00 22	—	—
5	FALSE ALARM	1824:00 28	—	—
6	STOP BOAT	1830:00 34	STOT BOAT	183001
7	SWIM (ALONG)	1836:00	—	—
8	SLOW (ACROSS)	1842:00 46	SLOW ACROSS	1842 30
9	SLOW (ALONG)	1848:00 52	SLOW ALONG	18 50 49
10	SWIM (ALONG)	1854:00 56	SECURED CAMERA WAS OFF	
11	SLOW (ACROSS)	1900:00 04		
12	SLOW (ALONG)	1906:00 10		
13	SWIM (ALONG)	1912:00 16		
14	SLOW (ALONG)	1918:00		
15	SWIM (ALONG)	1924:00		
16	SLOW (ALONG)	1930:00 34		

Figure 4.17. Water observer data form for (Camera 1, Monitor Station 2) .

4.4.4 Correction for Miscues and Traffic

The approach to reducing data was to count observation errors, on the assumption that such errors were fewer than successes. Figure 4.18 shows a form used to score the "X"s and "R"s by intrusion tactic and range, then to identify the "N"s and "T"s that had to be deleted from the planned event list, and finally correcting the event list at the bottom of the form. Figure 4.19 shows a completed form for an exceptionally accurate observer in daylight. This form shows that over half of the events were either misperformed or obscured by traffic.

4.4.5 Normalizing to Percent Success

Figure 4.20 shows the results of the next step of rationing the errors to total events, by type, and converting to success from failure. This form allows comparison of different observation vantage points and shifts (before versus after break). The left margin identifies the viewpoint (C5/M4 represents camera 5 as viewed at video monitor 4). The lighting illuminance at and distance to ranges A, B, and C are written in the matrices. The observer identity is included for comparison of human factors. The traffic obscuration percentage is also noted below each matrix.

4.5 PIER SURFACE SECURITY

This section discusses the data obtained from the test program related to pier security. Seven different lighting conditions were tested over five days. Approximately 8000 intrusions were conducted.

4.5.1 Daytime Traffic Impacts

The entire pier lighting program was conceived on the quite predictable assumption that daytime security is better than nighttime, so that lighting will help bring nighttime security up to a par with the daytime. The test program was carefully planned to confirm or deny this assumption. As it turns out, pier security during the day is seriously degraded by the intensive pier traffic preventing guards from viewing large portions of the pier surface from a single observation post.

Lighting: ________ Location: ________ Date: ________

Observer: ________ Monitor: ________

Apparent Errors

Early Shift

	A	B	C	TOTAL
RUN				
ROLL				
CRAWL				
STAND				
FALSE				
TOTAL				

Late Shift

A	B	C	TOTAL

Intruder Mistakes and Traffic

Early Shift

	A	B	C	TOTAL
RUN				
ROLL				
CRAWL				
STAND				
FALSE				
TOTAL				

Late Shift

A	B	C	TOTAL

Actual Events

Early Shift

	A	B	C	TOTAL
RUN				
ROLL				
CRAWL				
STAND				
FALSE				
TOTAL				

Late Shift

A	B	C	TOTAL

Figure 4.18. Form for separating intrusion errors and observer errors.

EXAMPLE OF FIELD COMPLETED DATA SHEET

Lighting: DAY **Location:** CS/[illegible] **Date:** 12/[illegible]

Observer: DAVEY **Monitor:** ______

Apparent Errors

Early Shift

	A	B	C	TOTAL
RUN	0	0	0	0
ROLL	0	0	0	0
CRAWL	0	0	0	0
STAND	0	0	0	0
FALSE	—	—	—	—
TOTAL	0	0	0	0

Late Shift

	A	B	C	TOTAL
RUN	0	0	0	0
ROLL	0	0	0	0
CRAWL	0	0	0	0
STAND	0	0	0	0
FALSE	—	—	—	—
TOTAL	0	0	0	0

Intruder Mistakes and Traffic

Early Shift

	A	B	C	TOTAL
RUN	1	4	5	10
ROLL	1	4	9	14
CRAWL	1	7	11	19
STAND	2	5	4	11
FALSE	—	—	—	—
TOTAL	5	20	29	54

[illegible] TRAFFIC

Late Shift

	A	B	C	TOTAL
RUN	0	0	6	6
ROLL	2	2	12	16
CRAWL	3	2	11	16
STAND	1	2	7	10
FALSE	—	—	—	—
TOTAL	6	6	36	48

2 TRAFFIC

Actual Events

Early Shift

	A	B	C	TOTAL
RUN	7	3	0	10
ROLL	11	7	0	18
CRAWL	8	3	0	11
STAND	5	1	0	6
FALSE	—	—	—	—
TOTAL	31	14	0	45

Late Shift

	A	B	C	TOTAL
RUN	4	5	0	9
ROLL	7	7	0	14
CRAWL	8	9	0	17
STAND	3	4	0	7
FALSE	—	—	—	—
TOTAL	22	25	0	47

Figure 4.19. Example of perfect observer but error prone intruders.

EXAMPLE OF FIELD COMPLETED DATA SHEET

Lighting: DARK   Location: ______   Date: 11/29

Observer: ______   Monitor: ______

SUCCESS

RESULTS ~~Apparent Errors~~

DAVEY Early Shift   HARRIMAN Late Shift

	A	B	C	TOTAL	A	B	C	TOTAL
1 RUN		75	100	86		100	100	100
4 ROLL		(45)	(33)	(43)		100	100	100
2 CRAWL		40	100	57		100	100	100
3 STAND		60	100	67		100	100	100
FALSE								
TOTAL		50	82	59		100	100	100

C/3 M/3   0% TRAFFIC

RESULTS ~~Intruder Mistakes and Traffic~~

BONAVENTURE Early Shift   Late Shift

	A	B	C	TOTAL	A	B	C	TOTAL
RUN	100	25		70	100	75		88
ROLL	83	45		65	100	78		89
CRAWL	100	78		89	91	100		95
STAND	83	100		90	100	100		100
FALSE								
TOTAL	91	61		77	96	90		93

C/5 M/4   1/2% TRAFFIC

Actual Events

DAVIS Early Shift   MCLENDON Late Shift

	A	B	C	TOTAL	A	B	C	TOTAL
RUN	100	40	0	57	100	80	100	93
ROLL	56	60	33	55	67	56	64	62
CRAWL	72	70	25	63	73	82	73	76
STAND	92	100	100	96	100	83	43	71
FALSE								
TOTAL	77	67	27	65	79	74	69	72

EYE REPLACED   3% TRAFFIC

6% TRAFFIC   59   67   1% TRAFFIC   88   98

Figure 4.20. Percent success for various observation points.

The data shows that a guard at the pier head, with no other duties such as inspecting identification, will miss around half of all intrusions due to pedestrian and vehicular traffic on the pier. Assuming this to be unacceptable, the apparent solutions include raising the observation point so as to look down on the pier or increasing the number and locations of guard personnel to limit the area surveilled by each. In the worst case it cannot take more than 8 personnel to essentially eliminate the traffic problem, since two back to back personnel can view the pier surrounding each of the moored ships even if each is simultaneously involved in loading operations.

Figures 4.21, 4.22 and 4.23 show the raw data and graphs of the traffic effects on visibility. Traffic is obviously a cumulative effect, increasing with distance due to distribution of traffic along the pier. Also, it is seen that traffic is somewhat time sensitive, decreasing near the end of the work day. One can probably extrapolate to a conclusion that observers at each end of the pier will experience only a 10 to 20 percent traffic problem, although it is clear that observing the entire pier length is essentially fruitless. Sun glare is also a factor in CCTV observation of the pier because the oil and rubber marred pier faces roughly southwest into the setting winter sun. Glint off the pier surface causes the camera automatic iris to stop down to the point where the scene is dark. The bottom graph of Figure 4.23 shows that raising the camera to 100 foot height, and raising the observation angle of the 1200 foot range from zero to five degrees, roughly halves the traffic problem. Data from camera 5 which faces away from the sun and looks down on ranges A and B at angles of 10 and 18 degrees respectively, reduces traffic interference to a secondary effect.

Figure 4.24 shows the relationship of traffic obscuration with the angle of vertical viewing. This graph suggests that three 100 foot high poles are required, as tested, in order to avoid daytime security from being severely limited by traffic interference. This is to say that four cameras or observers at 100 foot height can see over traffic quite well. It is also true that four observers free to station themselves appropriately on the pier surface will be able to avoid most traffic interference. Finally, we note that instead of viewing over traffic, one could choose to look across traffic by viewing from the moored ships. Figure 4.25 shows the falloff of visibility of rolling intruders with distance in daylight after subtracting out the effects of traffic. While some of this falloff may be due to glare effects, it is likely that this is a natural limitation in visual acuity. The angular subtense of the rolling intruder is only around 3 seconds of arc. Even in daylight it is counterproductive to expect guards to secure distances greater than around 600 to 900 feet away. This is consistent with the results of previous security field test data.

EXAMPLE OF FIELD COMPLETED DATA SHEET

Lighting: DAY **Location:** ________ **Date:** 12/1

Observer: ________ **Monitor:** ________

Apparent Errors

C5 / M4

DAVEY — Early Shift

	A 60'	B 90'	C	TOTAL
RUN	100	100	—	100
ROLL	100	100	—	100
CRAWL	100	100	—	100
STAND	100	100	—	100
FALSE				
TOTAL	100	100	—	100

15% TRAFFIC

DAVEY — Late Shift

	A 60'	B 90'	C	TOTAL
RUN	100	100	—	100
ROLL	100	100	—	100
CRAWL	100	100	—	100
STAND	100	100	—	100
	100	100	—	100

29% TRAFFIC

Intruder Mistakes and Traffic

ETC / KERCHON

MANZANARES — Early Shift

	A 60'	B 90'	C 120'	TOTAL
RUN	100	100	100	100
ROLL	100	100	0	59
CRAWL	93	100	75	59
STAND	100	100	~~—~~	100
FALSE				
TOTAL	98	100	62	93

37% TRAFFIC

MANZANARES — Late Shift

	A 60'	B 90'	C 120'	TOTAL
RUN	100	100	100	100
ROLL	100	100	11	65
CRAWL	100	100	57	55
STAND	100	100	0	60
FALSE				
TOTAL	100	100	32	77

19% TRAFFIC

Actual Events

C2 / M1

UDERMAN — Early Shift

	A 60'	B 90'	C 120'	TOTAL
RUN	100	100	100	100
ROLL	100	100	~~100~~	100
CRAWL	100	89	~~100~~	95
STAND	100	100	~~100~~	100
FALSE				
TOTAL	100	94	~~100~~	95

87% TRAFFIC

UDERMAN — Late Shift

	A 60'	B 90'	C 120'	TOTAL
RUN	55	33	0	56
ROLL	86	40	0	44
CRAWL	55	50	0	50
STAND	33	0	0	12
FALSE				
TOTAL	80	35	0	44

95% TRAFFIC 35% GLARE OUT

← THESE SCORES ARE REALLY ~90% w/o TRAF/GLARE

Figure 4.21. Daytime results in traffic.

EXAMPLE OF FIELD COMPLETED DATA SHEET

Lighting: DAY **Location:** ____ **Date:** 12/1

Observer: ____ **Monitor:** ____

Apparent Errors

Early Shift (BONA)

	A 60'	B 90'	C 120'	TOTAL
RUN	67	60	75	67
ROLL	100	100	83	96
CRAWL	75	25	100	72
STAND	67	67	100	70
FALSE				
TOTAL	81	67	88	79

23% TRAFFIC

Late Shift (BONA)

	A 60'	B 90'	C 120'	TOTAL
RUN	67	60	0	50
ROLL	75	80	0	48
CRAWL	100	62	33	61
STAND	100	60	25	50
FALSE				
TOTAL	81	65	15	53

12% TRAFFIC 15% GLARE?? MORE.

RESCORING TOO DIFFIC. GLARE STARTS EARLIER

G1 / M2

Intruder Mistakes and Traffic

Early Shift

	A	B	C	TOTAL
RUN				
ROLL				
CRAWL				
STAND				
FALSE				
TOTAL				

Late Shift

	A	B	C	TOTAL
RUN				
ROLL				
CRAWL				
STAND				
FALSE				
TOTAL				

C1 / M2 RESCORE

Actual Events ~~55% TRAFFIC + 35% GLARE~~

Early Shift

	A	B	C	TOTAL
RUN				
ROLL				
CRAWL				
STAND				
FALSE				
TOTAL				

Late Shift

	A 60'	B 90'	C 120'	TOTAL
RUN	100	100	—	100
ROLL	100	100	—	100
CRAWL	92	100	—	94
STAND	50	—	—	50
FALSE				
TOTAL	91	100	—	93

55% TRAFFIC + 35% GLARE

C2 / M1 RESCORE

Figure 4.22. More daytime results in traffic.

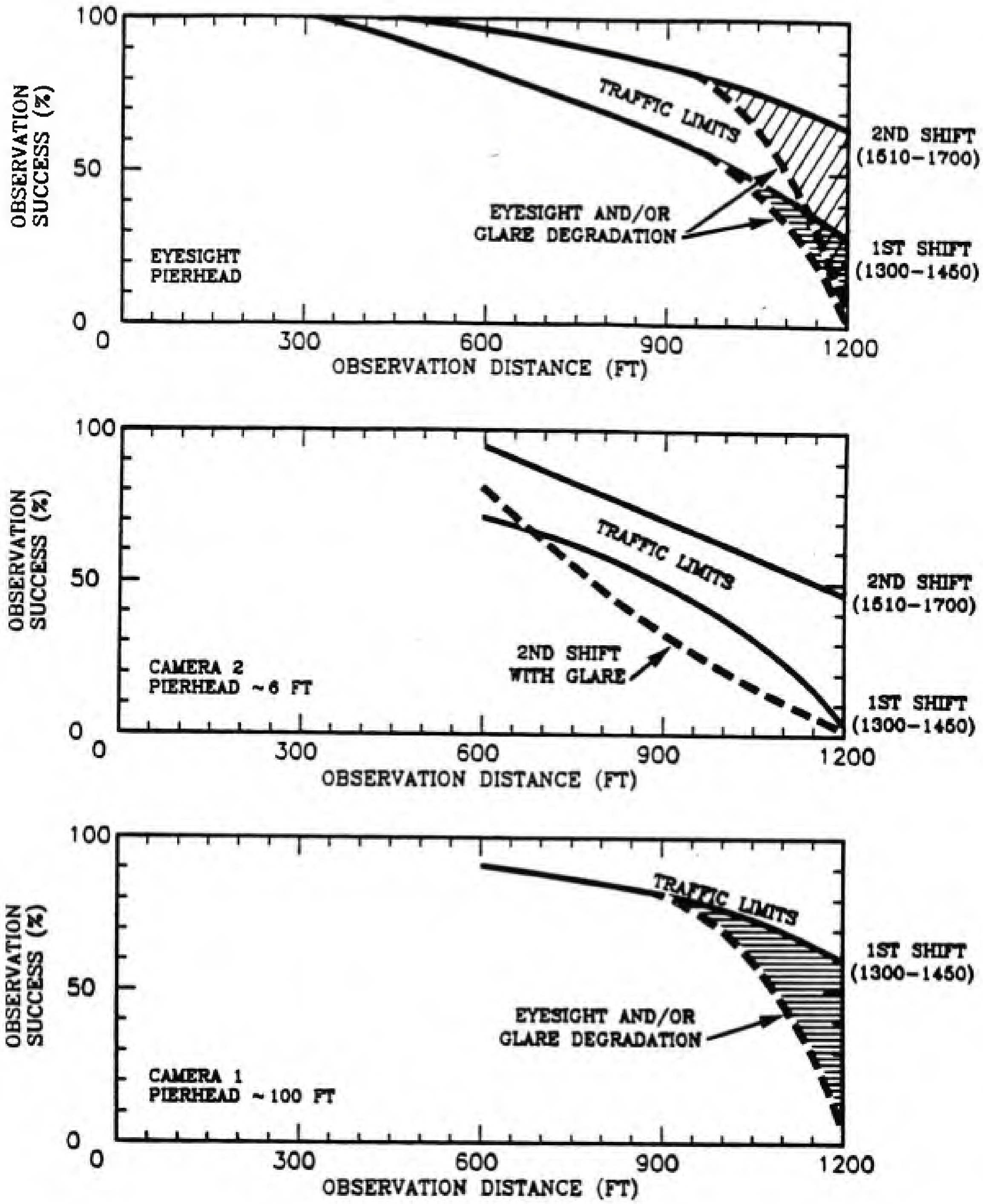

Figure 4.23. Traffic obscuration.

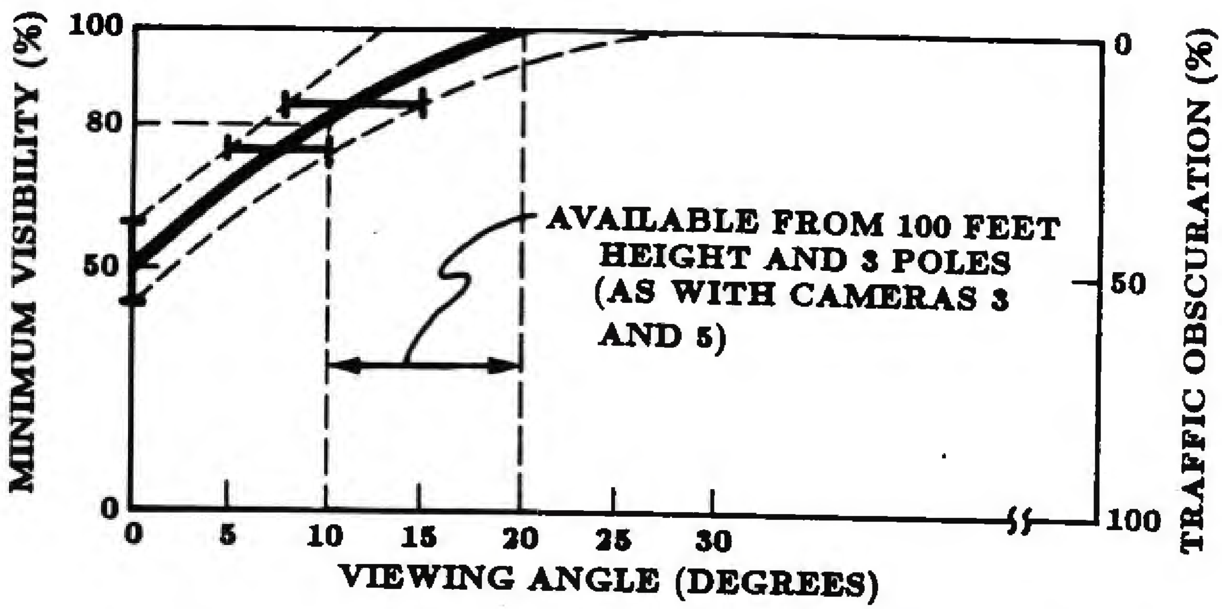

Figure 4.24. Effect of Observer Height on Visibility Due To Traffic Obscuration.

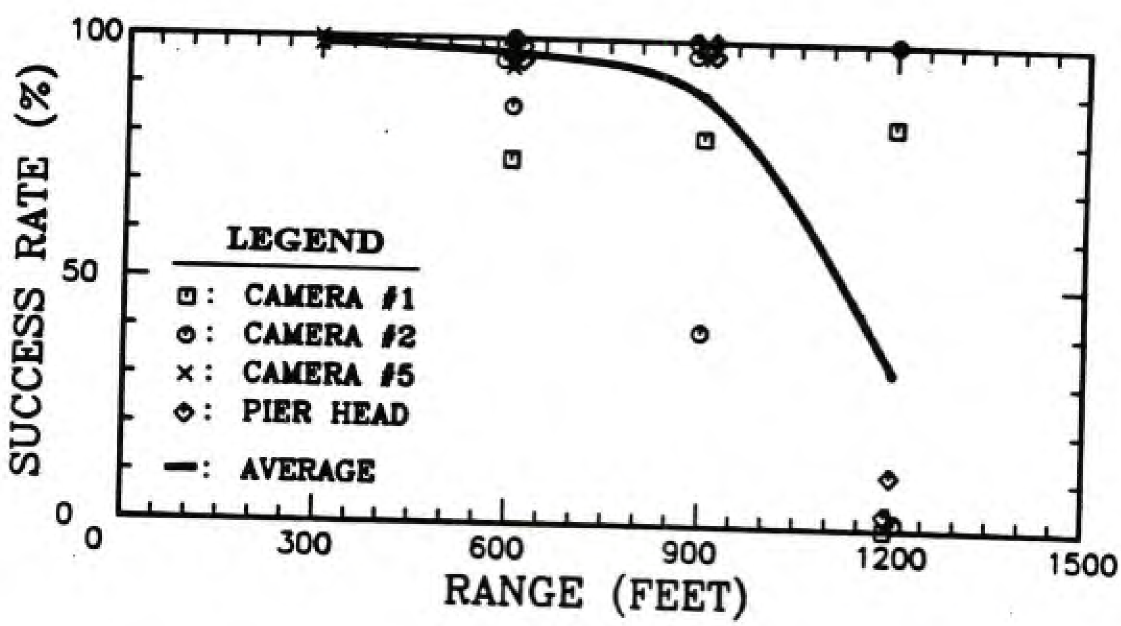

Figure 4.25. Daylight Distance Effects.

4.5.2 Current Night Security

The current darkened pier level of visibility was determined with the test lighting system turned off, but normal shipboard and pier lighting on. The ships used brow incandescent bulbs and the pier transformer lights were on. Late in the evening a half moon rose. The pier illuminance was measured at the surface using a hemispherical probe. The illuminance at range A can be summarized as 0.005 fc, while range B is 0.04 fc and range C is bright at 0.20 fc. Figure 4.26 shows a detailed plot of the upper hemisphere illuminance along the length of the pier. The two bright spots are caused by transformer lights. It may be important to note that range C is a bright spot as compared to the other two intrusion test ranges. This means that there is a bright spot behind ranges A and B when viewed at eye level from the pier head. This may in turn explain relatively high success rates in the relative darkness at ranges A and B.

Figures 4.26 and 4.28 show the observation success rate of rolling intruders versus distance and illuminance, essentially independent of both distance and lighting. There is wide scatter in the data. The level of observability is as great or greater than during the day at large distance (or observers are guessing around 50%). The level of observability is somewhat less than day at shorter distance.

In summary, if the current level of daytime traffic obscuration is of little importance, then neither is the current lack of nighttime lighting. It is fair to conclude that both deserve improvement.

4.5.3 Threat Tactics

In order to conserve effort and aid in understanding the relative effects of variables, this report focuses upon the relatively worst case rolling intruder data. However, some believe that less stressing threats warrant more attention. This section will analyze the relative observability of the various threat tactics of roll, crawl, run, and stand. The roll is the most difficult to detect by virtue of its small cross section presented to the observer and its slow speed. The run is the easiest to detect because of its opposite characteristics, unless the observer is inattentive resulting in a missing the action. The crawl and stand are intermediate threats in terms of cross section and speed, and therefore usually lie between the results obtained for rolls and runs. This is not uniformly true since people use differing search strategies for their observation.

Figures 4.29 and 4.30 show that the results of darkness testing averaged

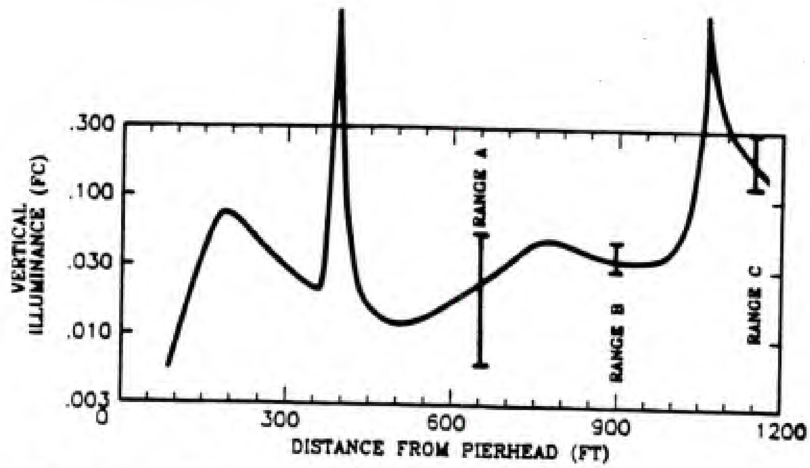

Figure 4.26. **Illuminance of the pier in darkness.**

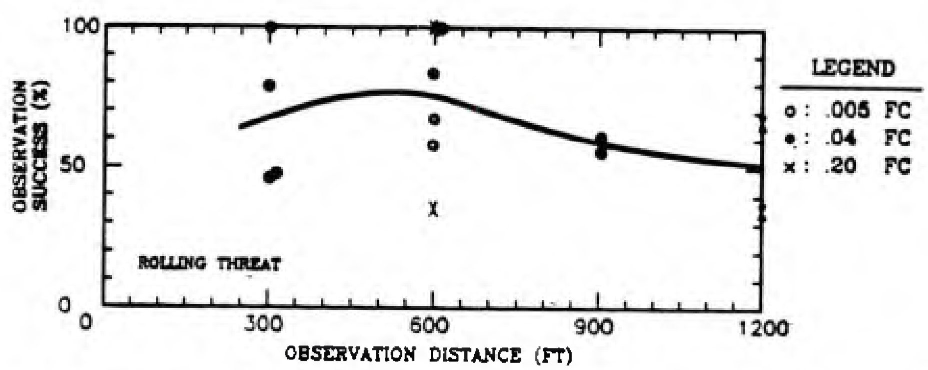

Figure 4.27. **Effect of observation distance rolling intruders in the dark.**

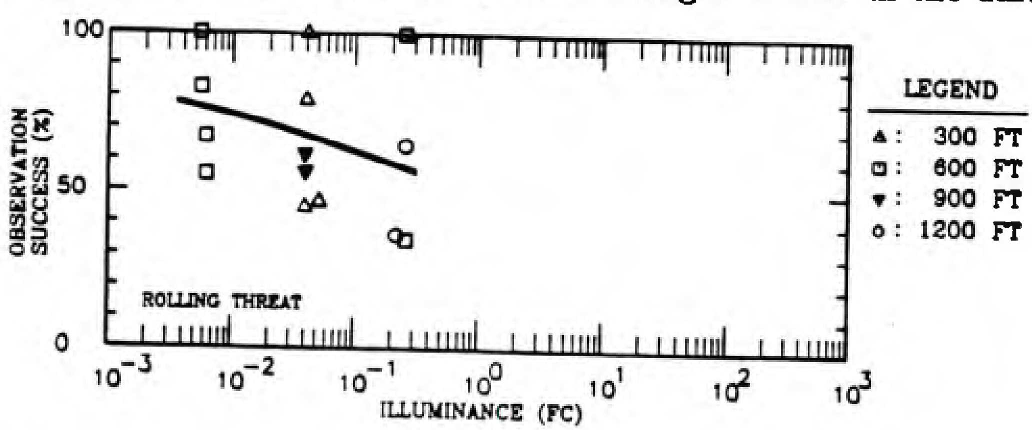

Figure 4.28. **Effect of lighting illuminance on rolling intruders in the dark.**

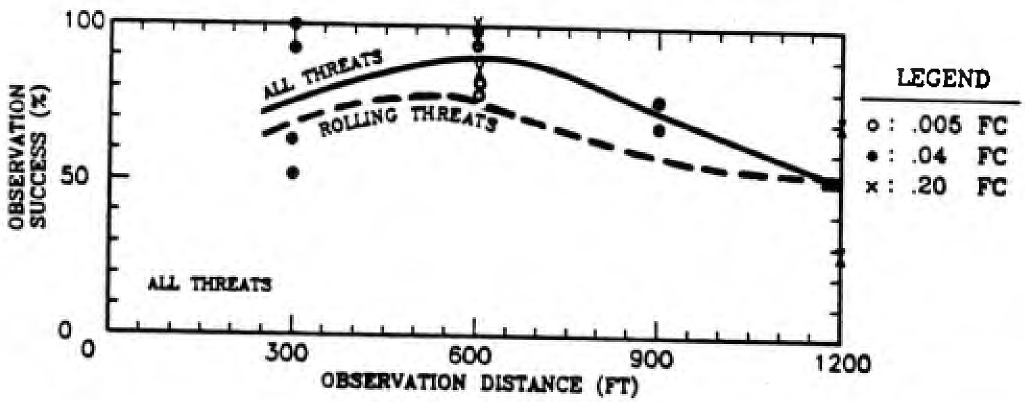

Figure 4.29. Effect of less severe threats versus distance.

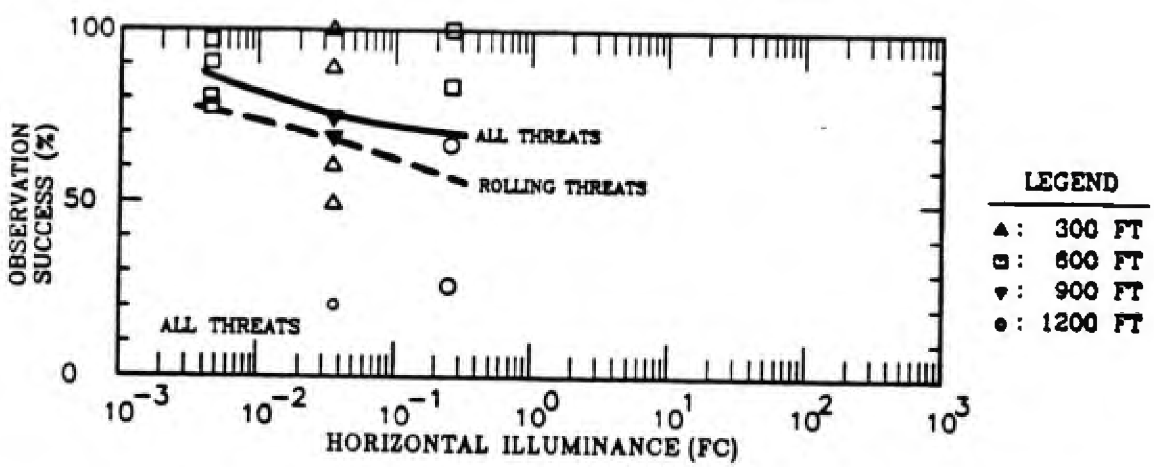

Figure 4.30. Effect of less severe threats versus illuminance.

over all threat tactics are roughly 10% higher than for the roll, whether examining the success versus distance plots or the success versus illuminance plots. In other words, there is less need for lighting if one focuses upon the less stressing threats.

4.5.4 Observer Reliability - Human Factors

This subject is one of the traditionally most frustrating facing security. The job of security guard is notoriously one of the most boring in existence due to the inactivity involved. That aspect of the job breeds inattentiveness which has been minimized in this test by telling the observers when to look for action. Motivation is a term applied frequently to human factors issues. It is evident that motivation has not been separated from this test program.

Many data sets in this test resulted in two different observers of nominally identical situations providing 0% and 100% observation success. While frequently the spread was more like + or - 30%, it was also + or - 50% all too frequently. Repeated attempts were made to isolate certain personnel as the problem slackards, this proved impossible in the long run. A few personnel were identified as superior performers and another set as inferior performers. These conclusions related only to attentiveness and not to visual acuity. At random times not easily correlated to lighting, threat, or vantage point, under achievers performed well and super-stars stumbled.

Human factors issues make it difficult to reach conclusions regarding the lighting required for Navy piers, since all the engineering issues are essentially second order effects when compared to variations in human performance.

Each of the data plots have been carefully prepared in order to allow the reader to see the human factors scatter in the data. The reader should pay close attention to the large magnitude of the differences between test subjects. It is not true that one subject is always the good observer and another is the poor. This is why security designers are always trying to eliminate the human in the loop. the preceding and following graphs should be held out to arms length in order to not dwell upon the line drawn through averages, but to see the large scatter.

4.5.5 Lighting Intensity

Figures 4.31 through 4.34 show observation success of rollers versus horizontal illuminance for observation distances of 300, 600, 900, and 1200 feet. These and

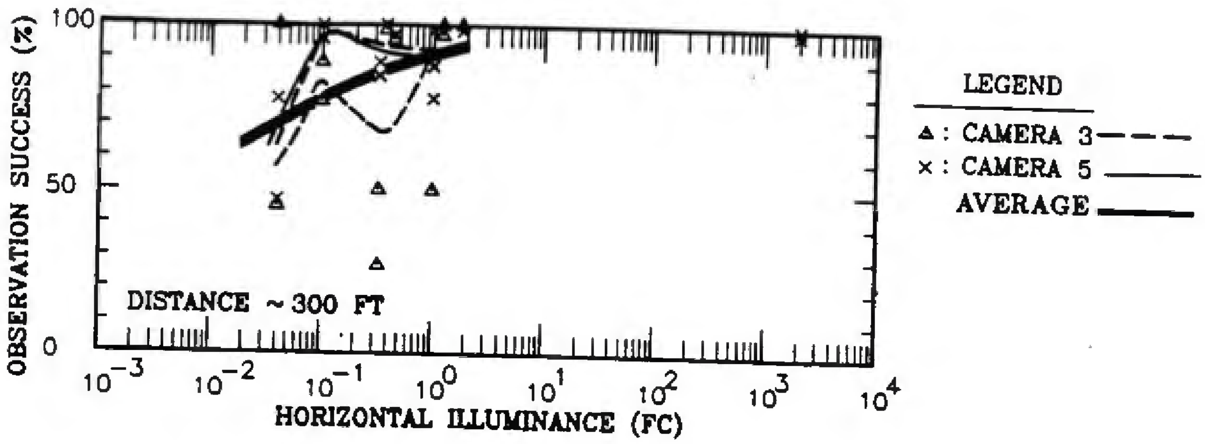

Figure 4.31. Pier roll success versus horizontal illuminance for 300 feet observation distance.

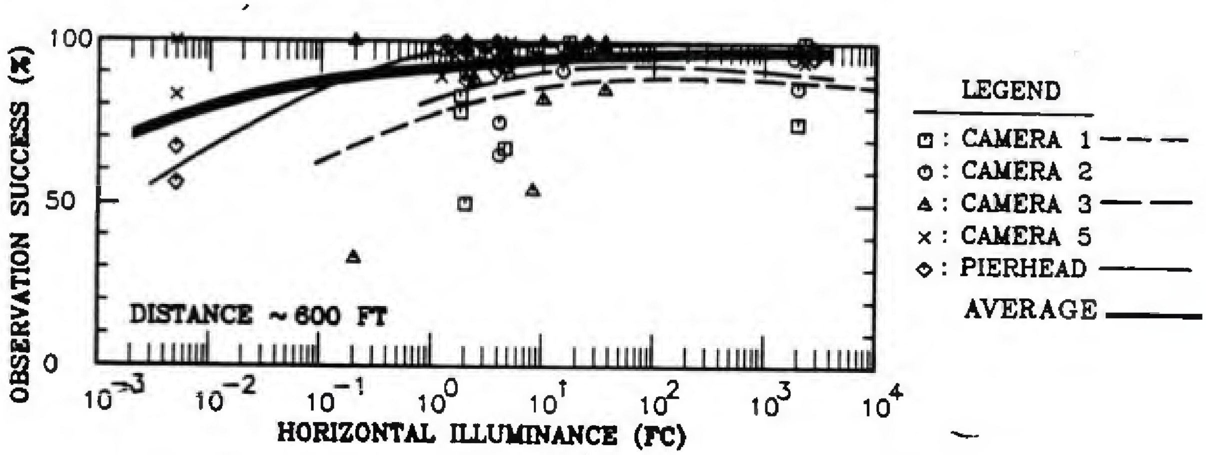

Figure 4.32. Pier roll success versus horizontal illuminance for 600 feet observed for distance.

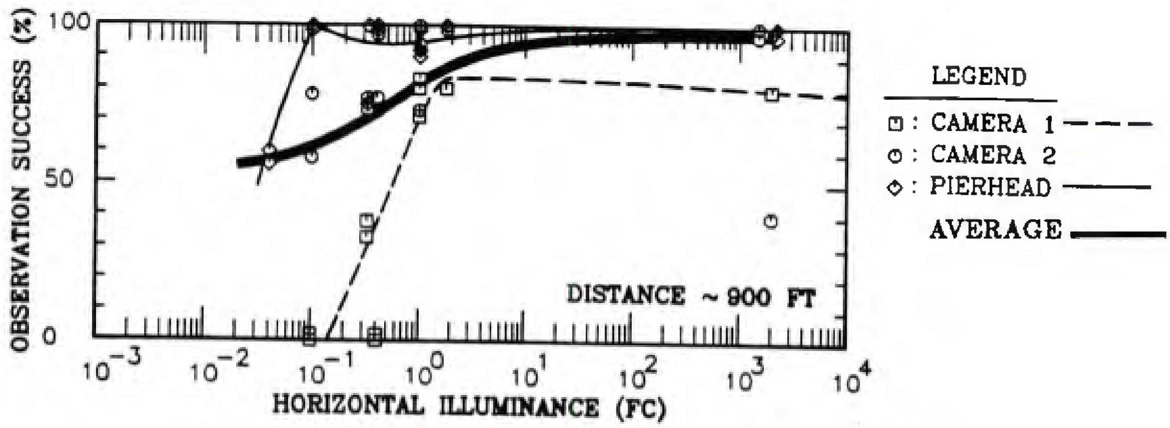

Figure 4.33. **Pier roll success versus horizontal illuminance for 900 feet observed for distance.**

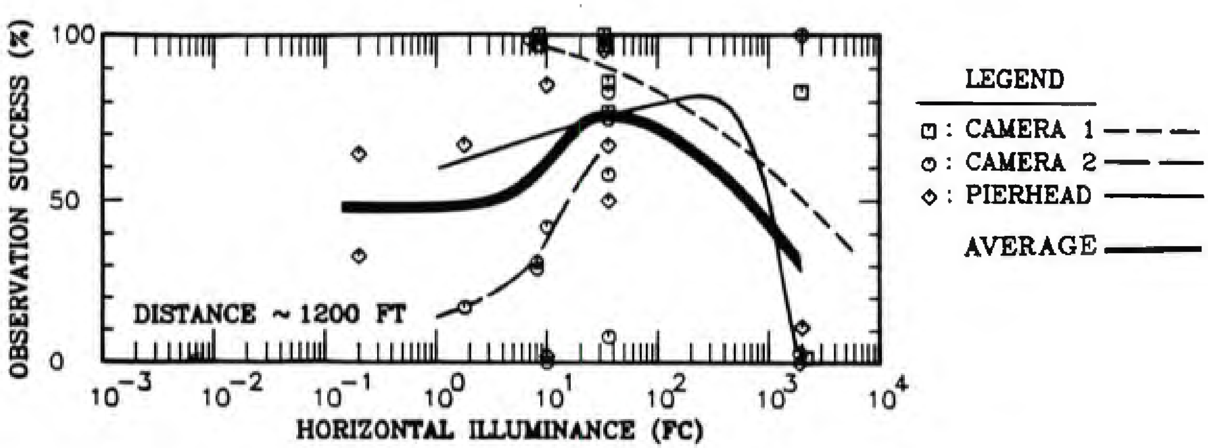

Figure 4.34. **Pier roll success versus horizontal illuminance for 1200 feet observed for distance.**

all similar figures in this section use a heavy solid line to portray a rough average of the plotted data.* Figure 4.32 shows very little sensitivity to lighting intensity at 600 feet. While respectable scores were achieved even in moonlight, slight improvements can be perceived as lighting intensity increases to full daylight. Direct human eyesight is seen from Figure 4.32 and 4.33 to be very nearly perfect with as little as 0.1 foot candles up to 900 feet. Figure 4.34, shows that for 1200 feet observation distance, lighting of any intensity doesn't provide good observation success of rolling intruders. Lighting also seems to make a difference at 900 feet distance, As Figure 4.33 shows a steepness of the curve below 1 foot candle. Under 600 feet distance, visibility appears good almost independent of horizontal luminance.

Figures 4.35 through 4.38 are plots of the same data correlated to vertical illuminance. Study of the averages of all data on each graph suggest the same conclusions as for the previous plots of horizontal illuminance. Under 600 feet even low illuminance is satisfactory, while at 1200 feet, results are uniformly poor in any lighting. At 900 feet, results become good with 2 foot candles.

Not included in this spread of data is the fact that direct human observation from the pierhead in even 0.3 foot candles vertical or horizontal illuminance provide nearly perfect scores for 600 to 900 feet distances. CCTV success is good to around 900 feet with 2 foot candles of lighting.

Pier lighting of 2 foot-candles can be suggested as providing acceptable security visibility without waste. Such lighting provides maximum benefit at distances of 700 to 1000 feet where vision is being stressed by small angular subtense. Below 700 feet distance it may be true that lighting is unnecessary and moonlight is almost as good. Above 1000 feet, all results indicate that lighting plays a minor role in improving visibility since threat objects are almost beyond the limits of resolution.

4.5.6 Observation Distance

Figures 4.39 through 4.43 examine observation success of rolling threats versus distance for the five camera viewpoints. Low, moderate and high horizontal lighting levels are coded on the data points. Figure 4.39 is the most unique of this set, exhibiting a significant dip at 900 feet and recovery at 1200 feet. This may be primarily the result of a preponderance of low lighting data at 900 feet and exclusively

*It should be noted that in this and all subsequence charts similar to Figure 4.31 through 4.34 the observation success point in percent are related to observations of a single person in a single night. When more than one point with the same symbol occurs for a given illuminance level, multiple people were involved.

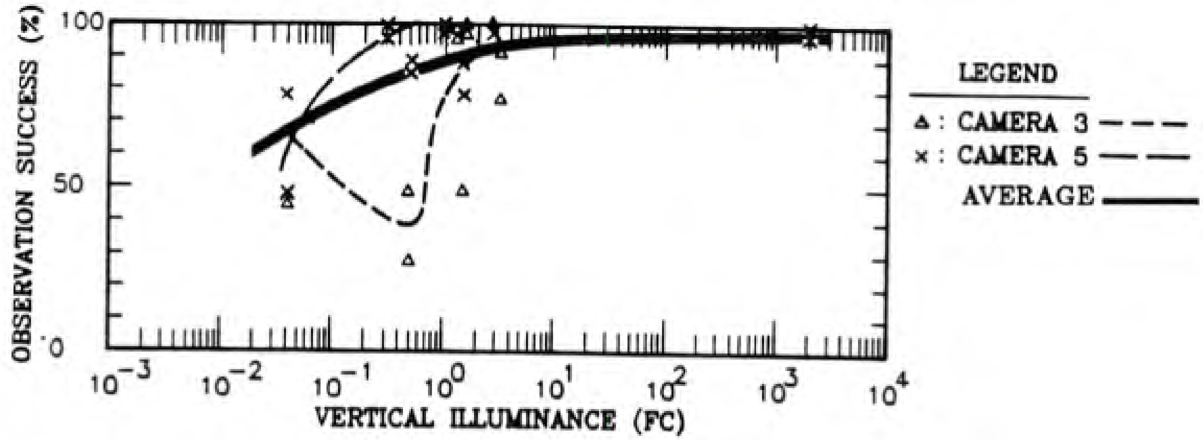

Figure 4.35. Pier roll success versus vertical illuminance for 300 feet observation distance.

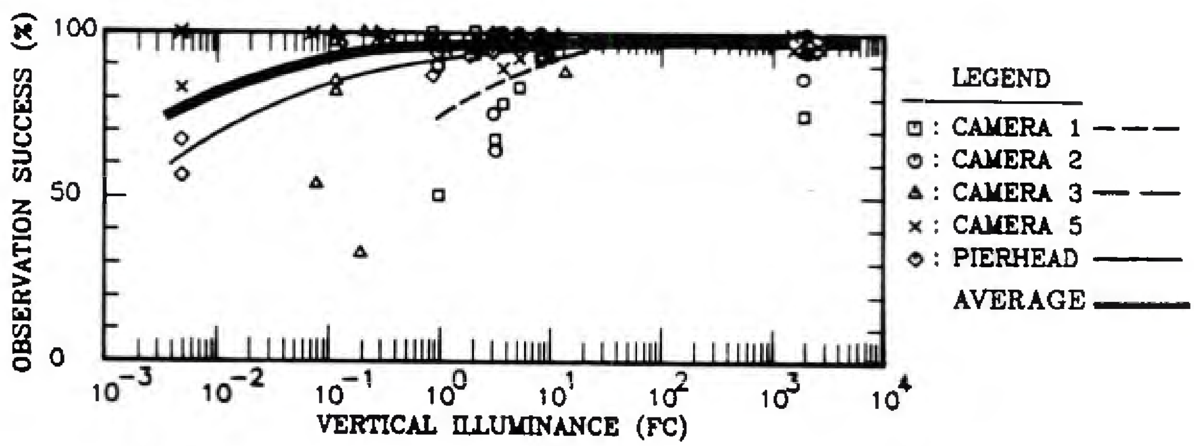

Figure 4.36. Pier roll success versus vertical illuminance for 600 feet observation distance.

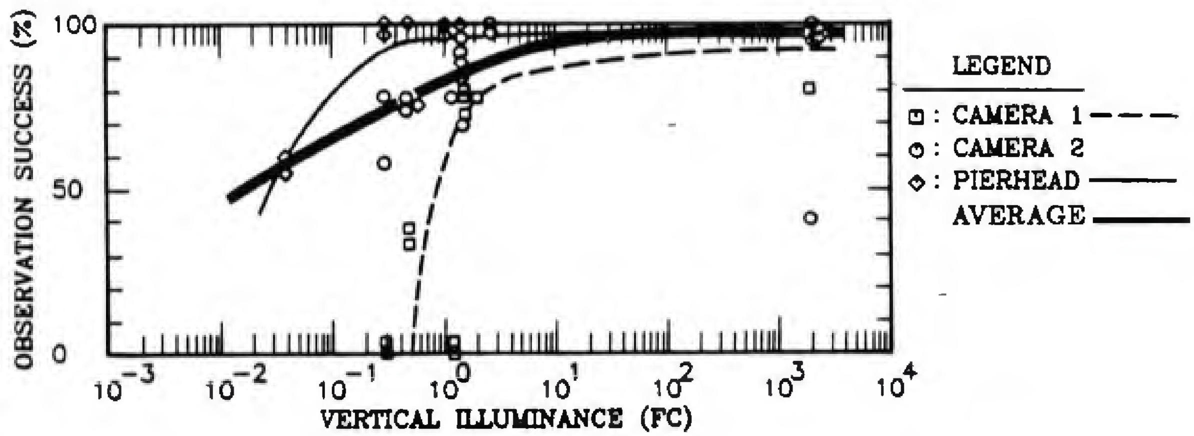

Figure 4.37. Pier roll success versus vertical illuminance for 900 feet observation distance.

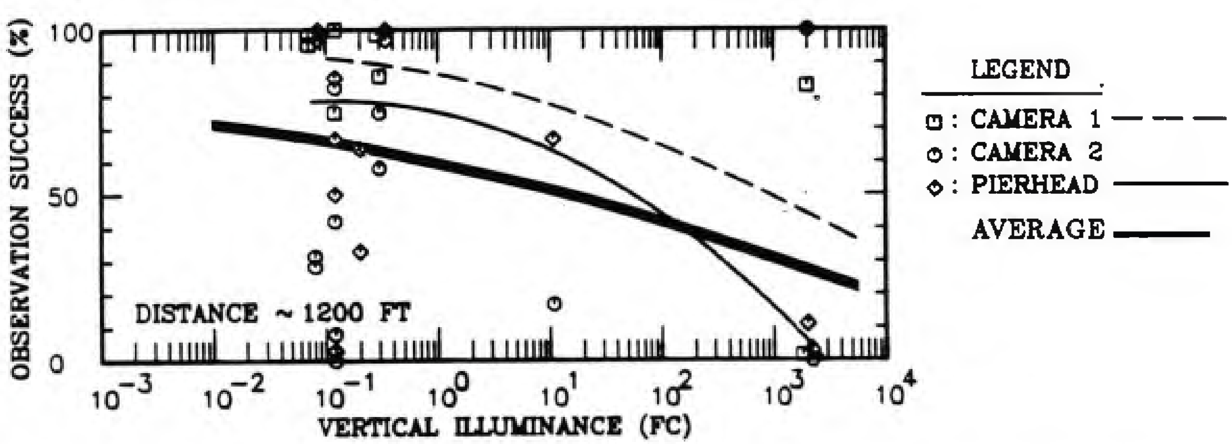

Figure 4.38. Pier roll success versus vertical illuminance for 1200 feet observation distance.

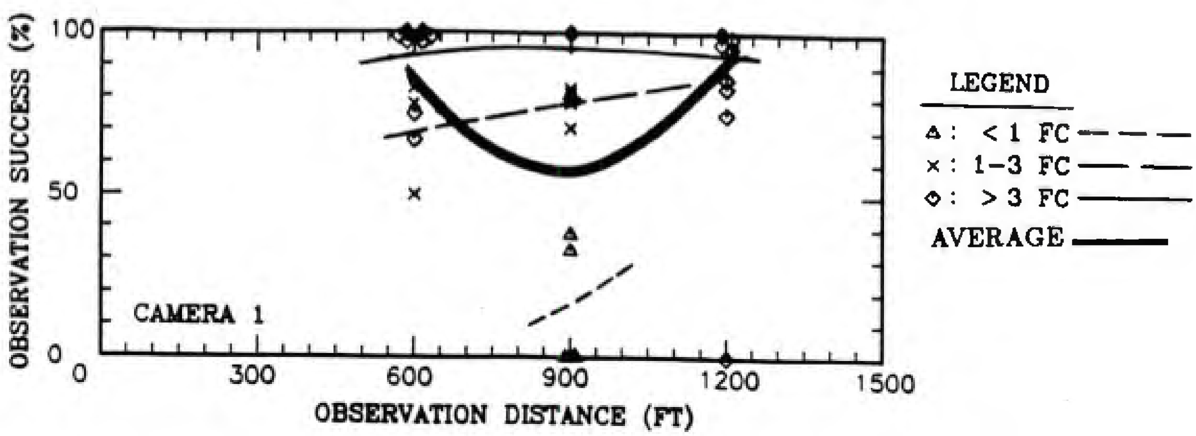

Figure 4.39. Pier rolling intruder observation success versus distance as seen from camera 1.

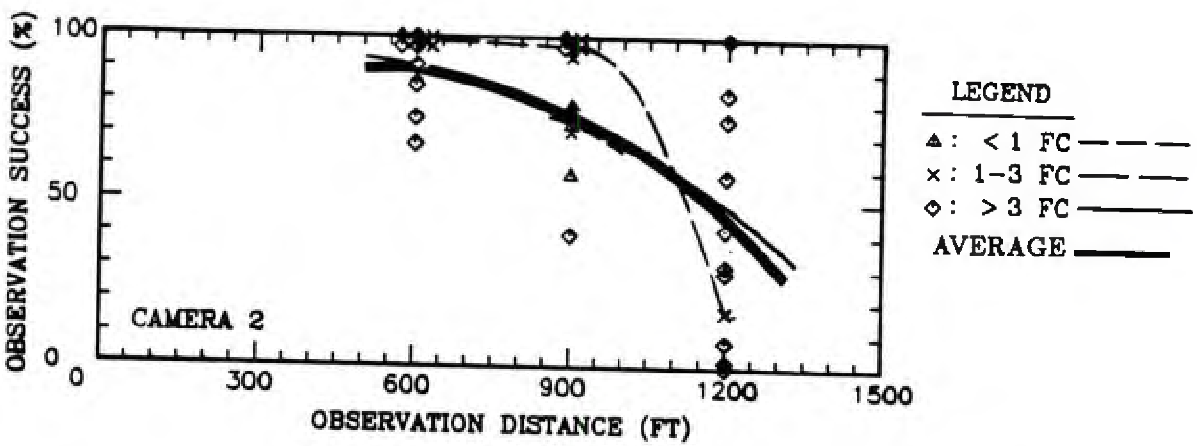

Figure 4.40. Pier rolling intruder observation success versus distance as seen from camera 2.

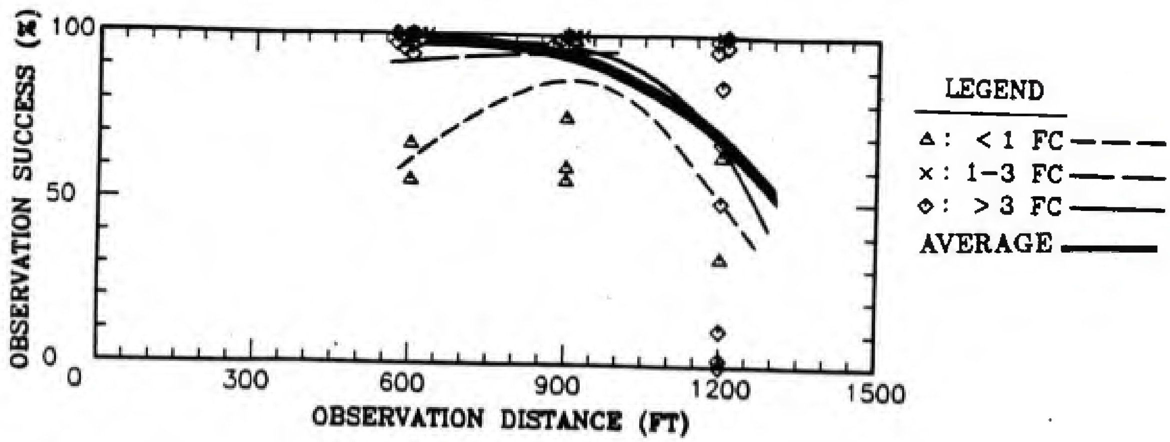

Figure 4.41. Pier rolling intruder observation success versus distance as seen by human from pierhead.

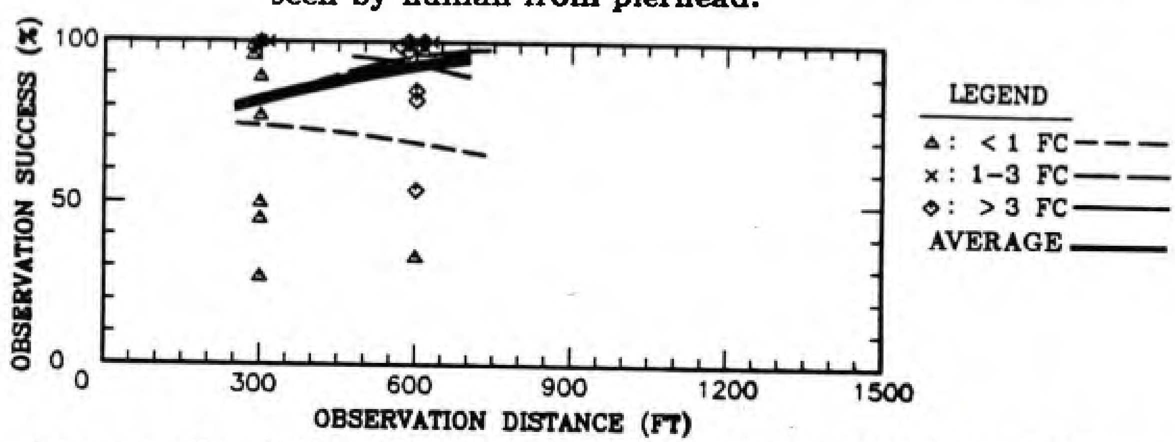

Figure 4.42. Pier rolling intruder observation success versus distance as seen from camera 3.

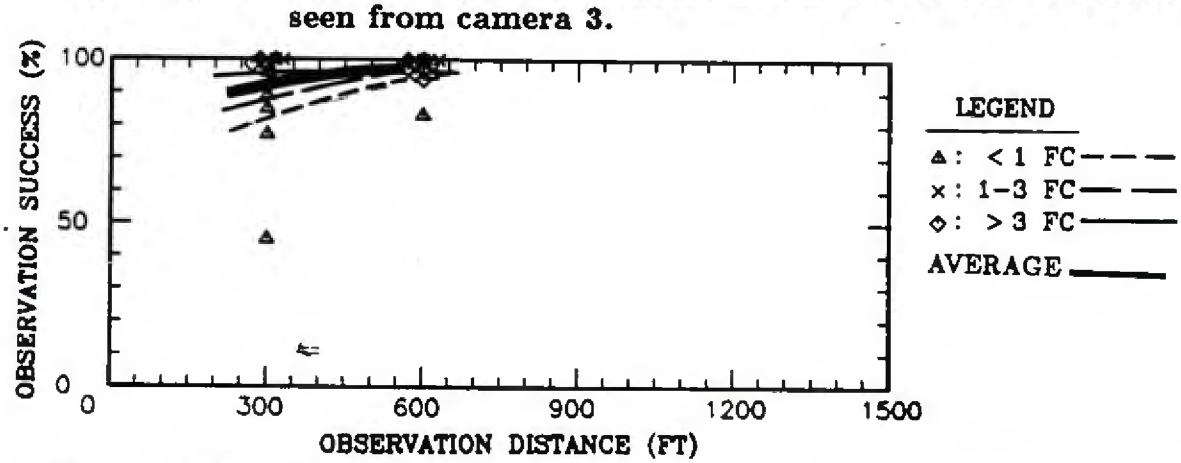

Figure 4.43. Pier rolling intruder observation success versus distance as seen from camera 5.

high lighting level data at 1200 feet. If an upward adjustment of the 900 foot data would be more comparable with the other four graphs, then Camera 1 appears again to offer a slight advantage, especially at long distances near 1200 feet. This effect could easily be the result of lower glare sensitivity of Camera 1 in sunset conditions. At distances of 300 to 600 feet, all cameras provide excellent observation success in all but the worst lighting conditions. At 900 feet, scores are all noticeably reduced, although direct human eyesight seems the least affected by the distance. Prior studies for the Army MERADCOM indicated a reduced visibility beginning around 800 feet observation distance also. Finally, Camera 2 shows the greatest sensitivity to the combined effects of distance and sun glare. This is probably related to the low angle of observation and the dynamic range limits of the camera.

4.5.7 Viewing Aspect and Observer Aids - CCTV

The test program was structured to determine the effect of observation distance and vertical viewing angle of the success rate. The positions of each of five video cameras was discussed in detail in Section 3.4.3. Figure 4.44 shows the locations of these cameras again. Camera 1 is a 50 mm lens that looks out the entire length of the pier from 100 feet up pole 1 near the head of the pier. Camera 2 is a 75 mm lens that looks out the entire pier length from below Camera 1 at around 6.5 feet eye height. Camera 3 uses a 50 mm lens halfway out the pier on pole 2 at nearly 100 feet height looking at ranges B and C. Camera 4 is not used for active security testing. Camera 5 uses a 50 mm lens at the water end of the pier looking back at ranges A and B from a height of 75 feet up the navigation tower.

Figures 4.45 through 4.49 show the percent observation success of rolling threats versus horizontal illuminance each viewing location. The viewing distances are coded in the symbols of each plot.

The average of all distance data for Camera 1 and the human pierhead data show a steep dependence upon lighting intensity, suggesting 1 to 3 horizontal foot candles is good. Figures 4.46 and 4.47 allow inspection of the 1200 feet data separately and show that, while 30 foot candles may be best at these low angles, the results are never acceptable in any lighting. Inspection of all other distances show cameras justifying 2 foot candles, while human observation can suffice with 0.3 foot candles, out to 900 feet distance.

Figures 4.50 through 4.54 confirm all of the same conclusions even thought plotted versus vertical plane illuminance.

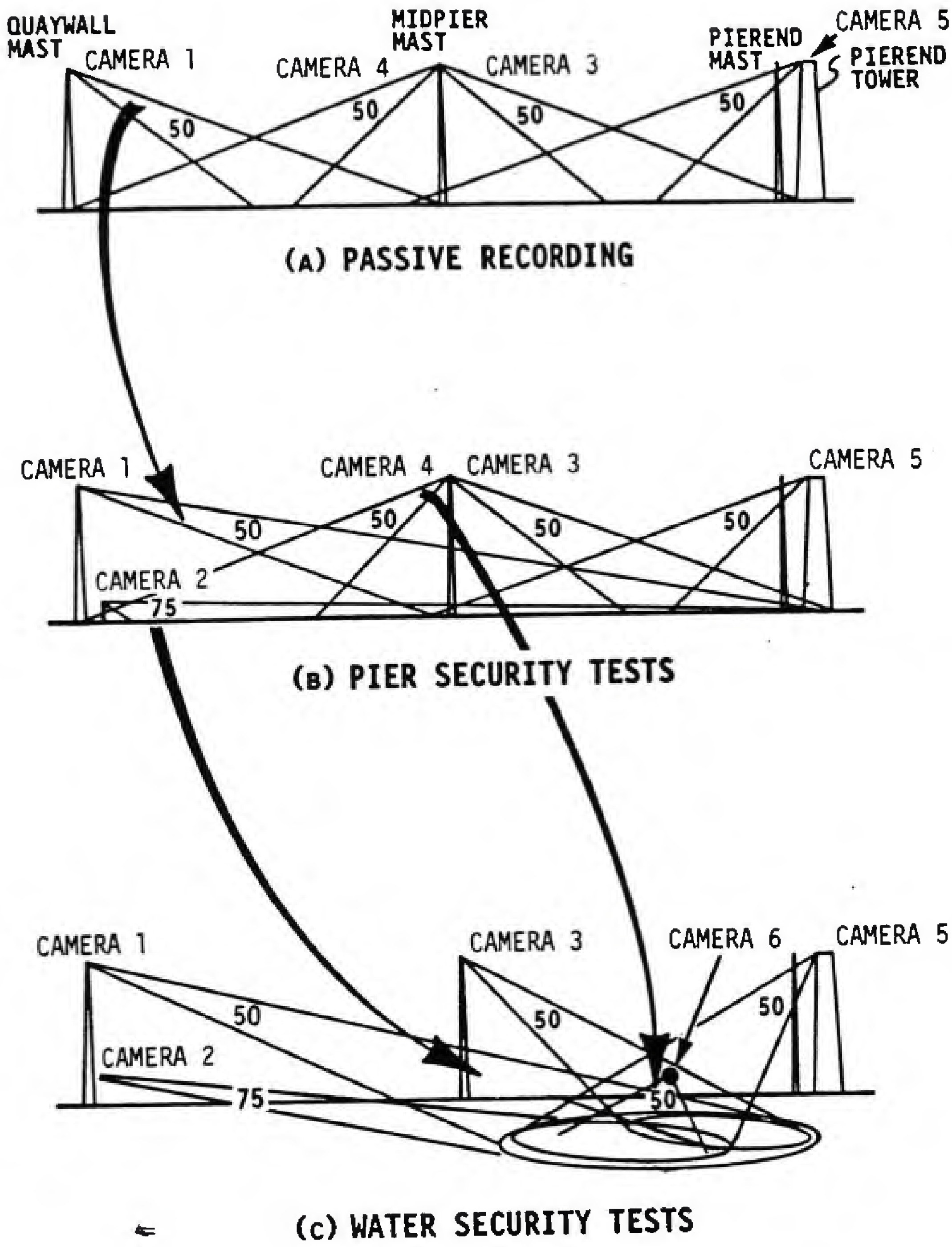

Figure 4.44. Camera locations.

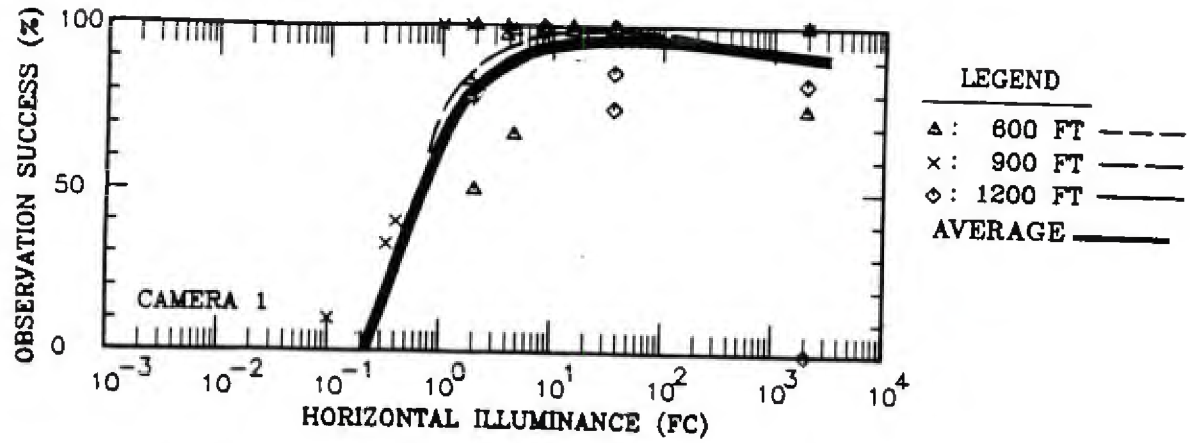

Figure 4.45. Pier rolling intruder observation success as a function of horizontal illuminance as seen from camera 1.

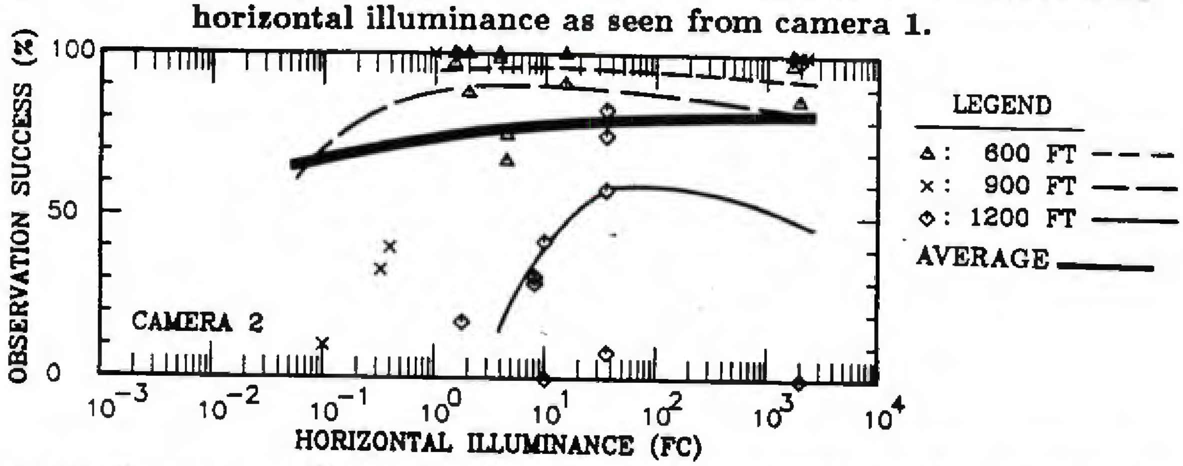

Figure 4.46. Pier rolling intruder observation success as a function of horizontal illuminance as seen from camera 2.

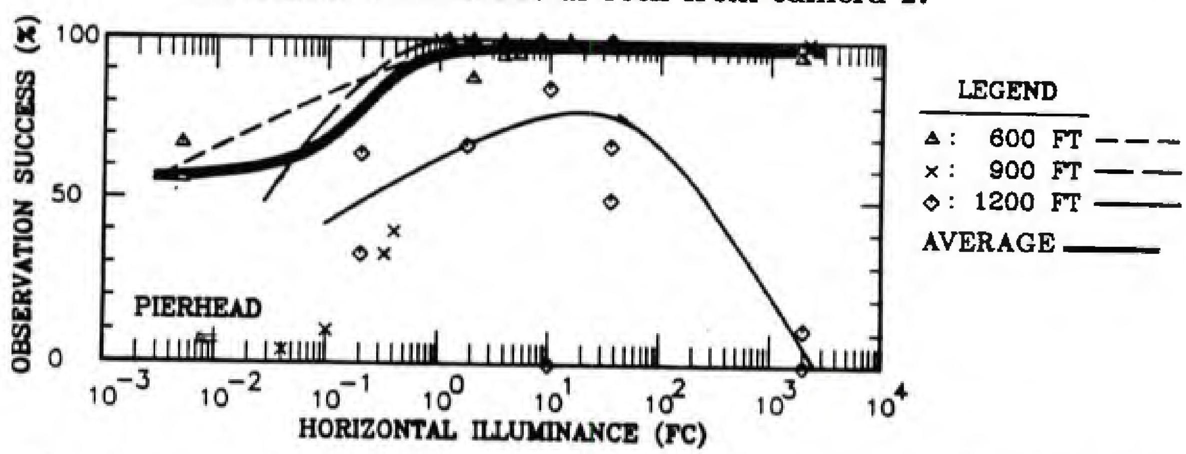

Figure 4.47. Pier rolling intruder observation success as a function of horizontal illuminance as seen from a human at pierhead.

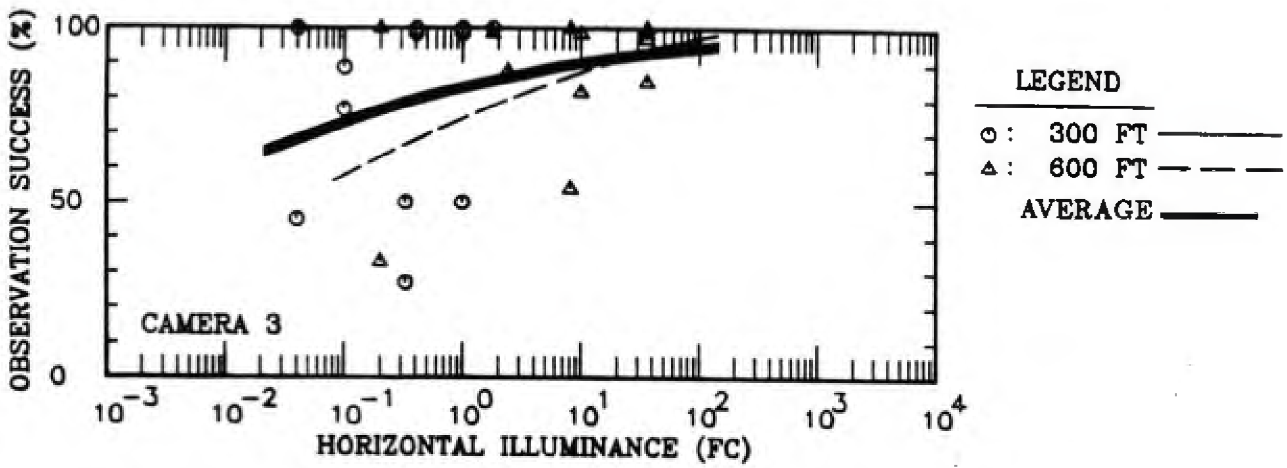

Figure 4.48. Pier rolling intruder observation success as a function of horizontal illuminance as seen from camera 3.

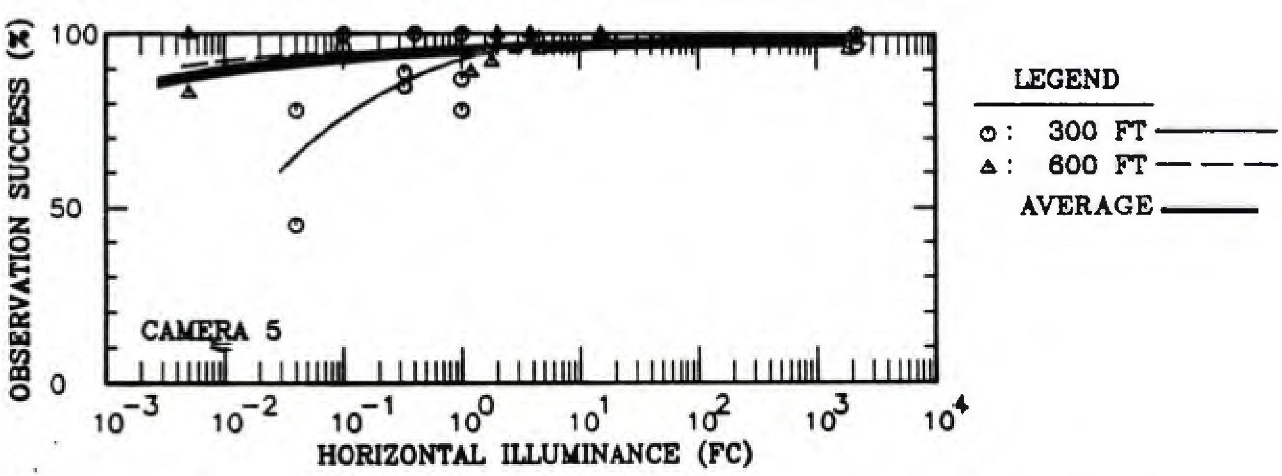

Figure 4.49. Pier rolling intruder observation success as a function of horizontal illuminance as seen from camera 2.

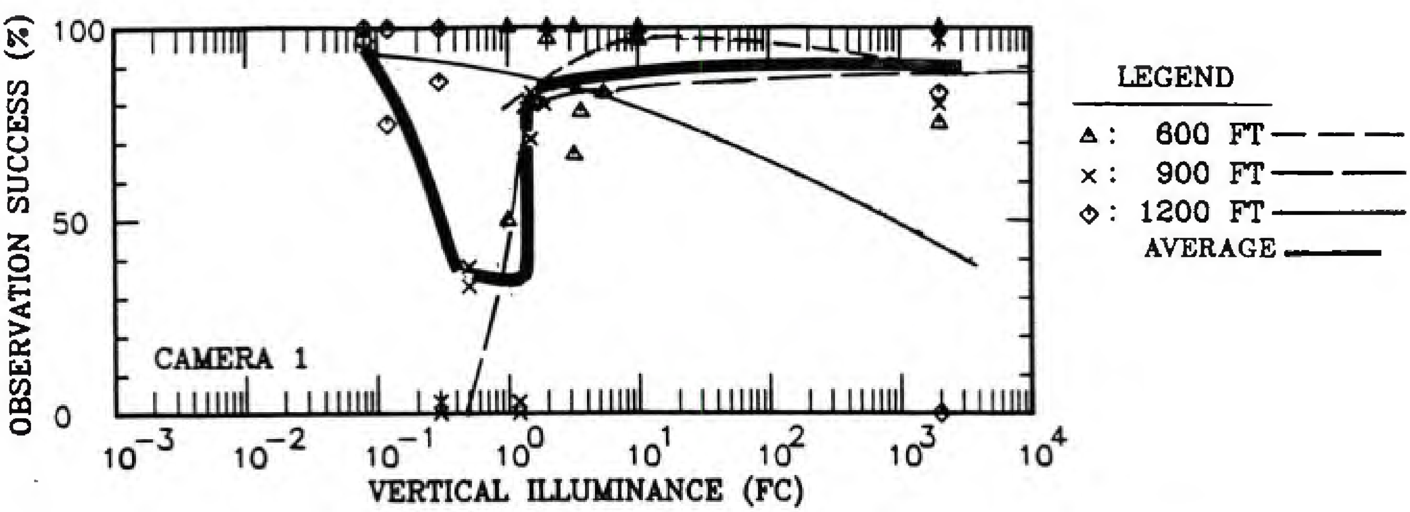

Figure 4.50. Pier roll success versus Vertical Illuminance for Camera 1.

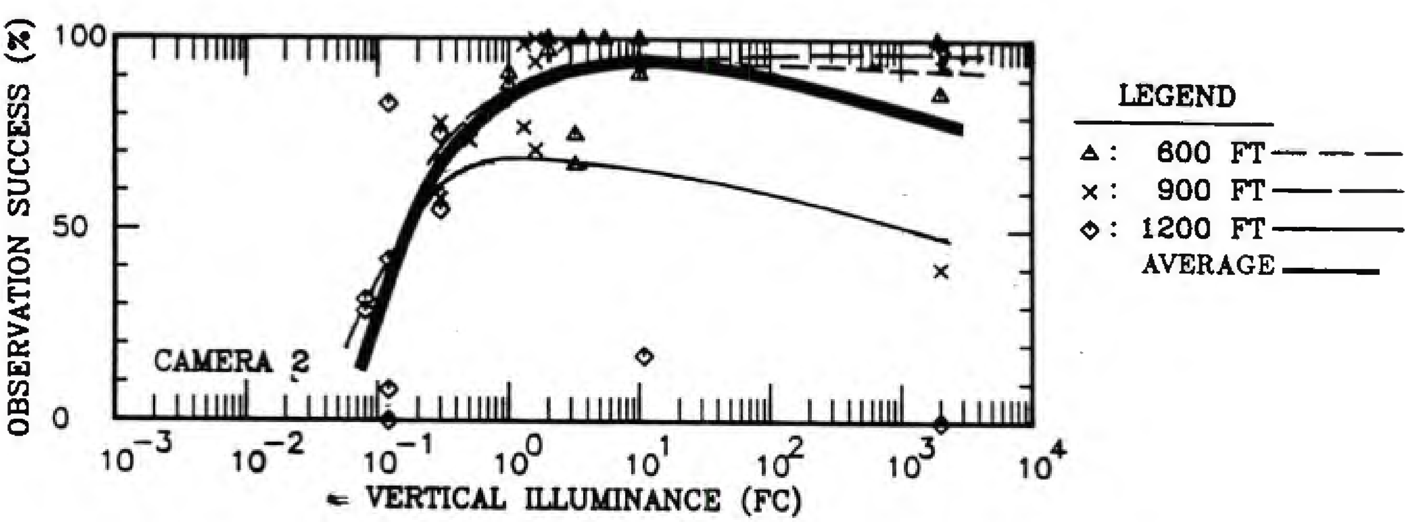

Figure 4.51. Pier roll success versus Vertical Illuminance for Camera 2.

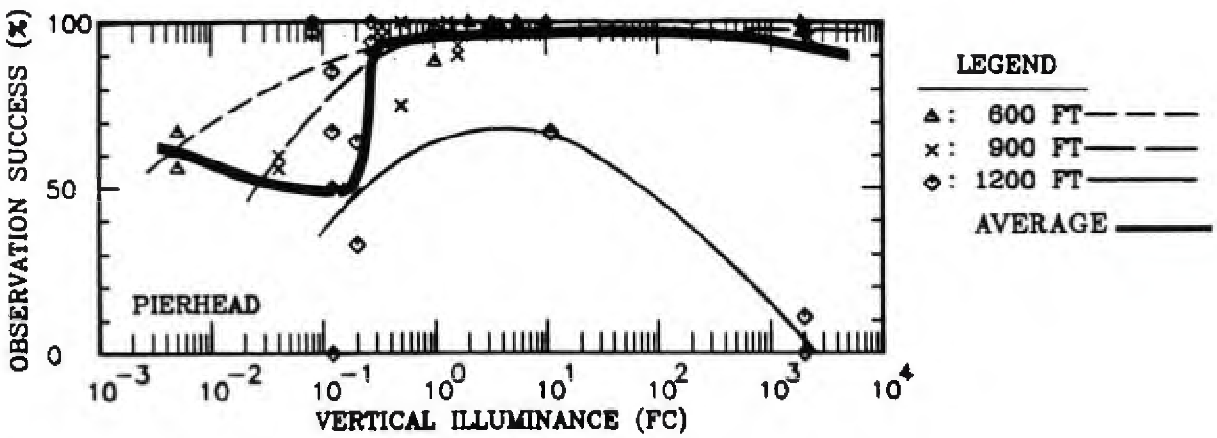

Figure 4.52. Pier roll success versus Vertical Illuminance from Human at Pierhead.

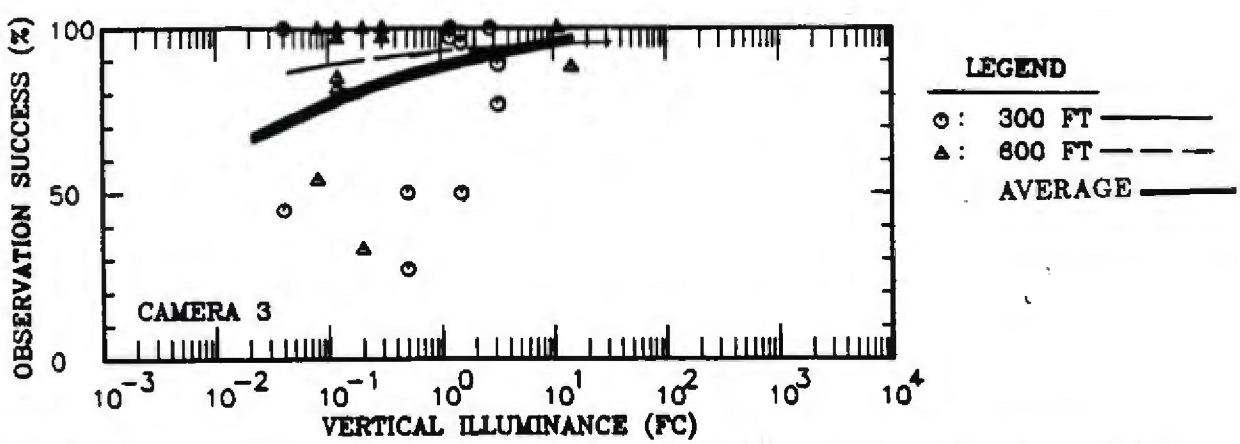

Figure 4.53. Pier roll success versus Vertical Illuminance for Camera 3.

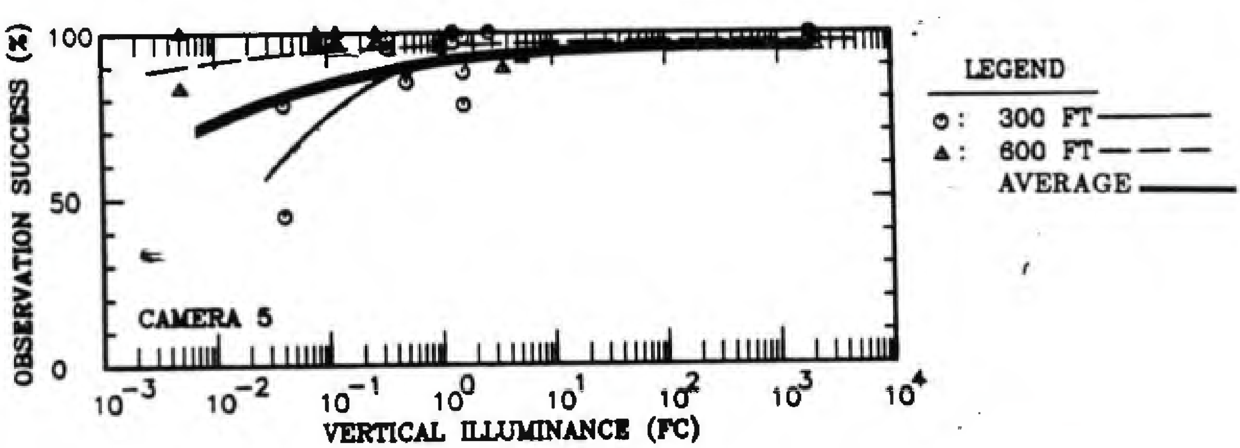

Figure 4.54. Pier roll success versus Vertical Illuminance for Camera 5.

The human observer is better than CCTV aided observer, and needs less light. It would appear from examination of the total data set that CCTV does not offer first order visibility performance enhancement. Instead, CCTV may only be of first order economic benefit in providing an affordable observation platform.

4.5.8 Glare

Three manifestations of glare were encountered in the test program. First, there was sun glare off the pier surface to the observer in the late afternoons. Second, there was glare of the pier lighting luminaires directly into the eyes of observers. Third, car headlights caused direct glare in camera irises at night. Sun glare off the pier surface can be a problem at some time of the day and year unless observation can be generally northerly. While controlled degrees of sun glare can be beneficial by providing a surface "sheen" against which to view threats in a condition known as negative contrast with optical gain, too much saturates the observer dynamic range limits. CCTV cameras were noted as being more sensitive to this sun glare than the human eye, because of a more restricted automatic iris dynamic range. If traffic obscuration encourages cameras looking in opposite directions, then one will experience glare saturation at some time of the year unless the camera height can be adjusted to reduce specular reflection. An alternative is to rely upon several personnel as observers instead of CCTV. Their mobility relative to traffic and greater glare tolerance will mitigate this issue.

Direct lighting glare from the luminaires is a concern to pier security surveillance, pier operations, and ship piloting. The prototype lighting system was designed with careful attention to the number and aiming of luminaires, limiting glare by downward directed lighting and 100 foot poles. The design penalty for almost eliminating luminary glare was about a factor of three more luminaires and significant lighting variation in the form of "hot spots". A test was performed with a different luminary aiming concept exhibiting increased glare, but using far fewer luminaires and resulting in almost total uniformity of pier illuminance. This degree of glare can be described as lights aimed into the observer eye only 5 and 9 degrees above the line of sight. The lighting illuminances produced were 1 and 2 foot-candles. Observation success scores for this lighting approach were uniformly high-between 71% and 100%, and averaging 92%. for distances to 900 feet. It is hard to make convincing argument that this glare was debilitating. Instead, this system was efficient at providing illuminance in the vertical plane.

Problems with car headlights were noted when viewing with CCTV. Car headlights caused camera automatic irises to shut and prevent observation of the scene. If sufficient lighting is provided for Navy piers to allow safe driving a slow speeds, and CCTV is employed to maintain security surveillance, then cars must be ordered to douse headlights upon entrance to the pier.

4.6 WATER SURFACE SECURITY

NAVSTA San Diego is not alone in its intent to provide port security from the open channel using a police patrol boat. Two such boats have recently been acquired and activated at NAVSTA San Diego. These boats are not currently operated at night in a continuous patrol mode, although such a plan has been suggested as an eventual standard operational practice. Presently the boats are operated in a patrol mode during the day and alarm response mode at night. Such plans recognize that threats to Navy ships from the water are of real concern. This test program was designed to provide quantitative information on the effectiveness of water lighting in securing the water surface against intrusion.

The lighting arrangements used for the water phase of testing were, of course predicated upon the same three 100 foot pole lights as the pier surface.

The luminaires were re-aimed toward the water surface between piers five and four. Two thirds of the luminaires were directed toward the water, and provided an acceptable degree of lighting uniformity on the water surface. Four lighting illuminances were tested: dark (0.006 fc), 50 foot height lights (0.113 fc), 100 foot height lights (0.36 fc), and daylight. The intrusion tests were performed on the quarter of the water surface between piers four and five that was closest to the outer end of pier four. This area was located in a way that was enforceable - where lights could shine over moored ships and observers could see around such ships.

4.6.1 Observation distance

Figure 4.55 shows the results of swimmer observation success versus distance for parametric illuminance. This shows that in daylight or 0.36 foot-candles illuminance the observation success is relatively acceptable and independent of distance. It also shows that if distance is within 600 feet, even unlighted water provides quite good observation success. Figure 4.56 displays the data derived exclusively from direct

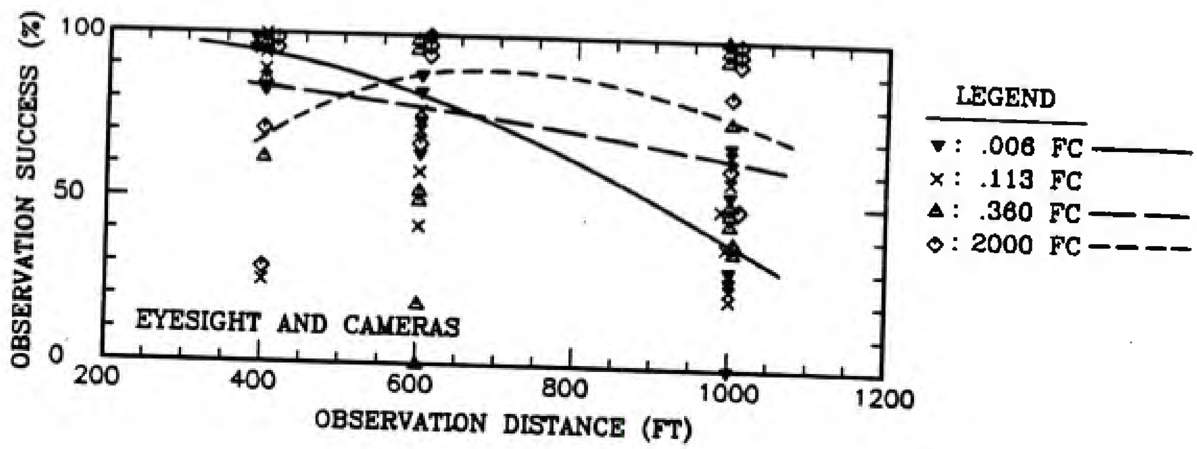

Figure 4.55. **Observation of swimmer versus distance.**

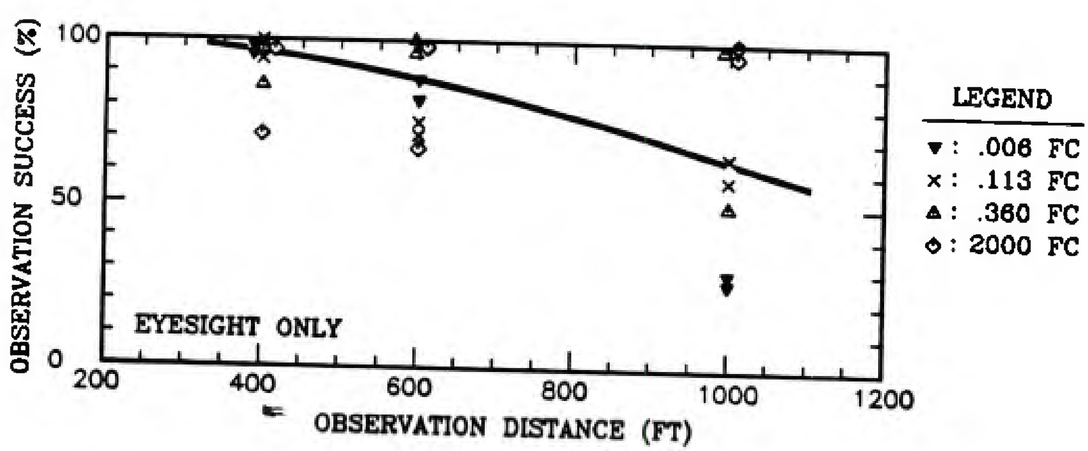

Figure 4.56. **Human observation of swimmer versus distance.**

human observation. This shows that the conclusion of good success rates within 600 feet is even clearer. It also shows the sensitivity to increased distance more clearly.

If observers are stationed on each moored ship and/or on a patrol boat and the quaywall, all portions of the water area between piers are within 700 feet of an observer. Such a deployment of personnel would appear to make lighting of the water surface unnecessary, even for detection of swimmers.

4.6.2 Lighting Intensity

Figure 4.57 shows the swimmer observation success versus lighting horizontal illuminance for parametric distance. Clearly evident is the weak sensitivity to lighting intensity for close observation distances and the stronger dependence at longer distances. It is an unexplained surprise that the success rates are lower for the illuminated water surface cases than for either the daylight or dark tests. Figure 4.58 shows the same results when only human eyesight is plotted - ignoring all camera data. The same results are evident although somewhat more clearly.

Even in daylight, observation of swimmers will apparently range between 70 and 100 percent with human surveillance and between 30 and 100 percent using CCTV. If the patrol boat is relied upon exclusively to observe swimming threats, its success should be expected to be low because of the potentially long distances up to 1500 feet.

At night without lighting from the prototype system, there are a large number of shipboard and shoreside lights that glint on the water in a manner that aids intruder visibility. The effect is one of creating a very shiny mirror-like surface against which all activity, even wakes are quite visible. Technically this is a manifestation of negative contrast with optical gain that is particularly helpful from the patrol boat. It is also true that the glare off the water from the luminaires was severe - a possible explanation for the low scores that resulted with the lights on.

4.6.3 Viewing Aspect and Observer Aids - CCTV

Figures 4.59 through 4.61 show swimmer observation success versus illuminance for various distances and coded observation locations. It is evident in each of these plots that the human observers were superior to the CCTV aided observers. This could be the result of many test factors including the difficulty of aiming camera

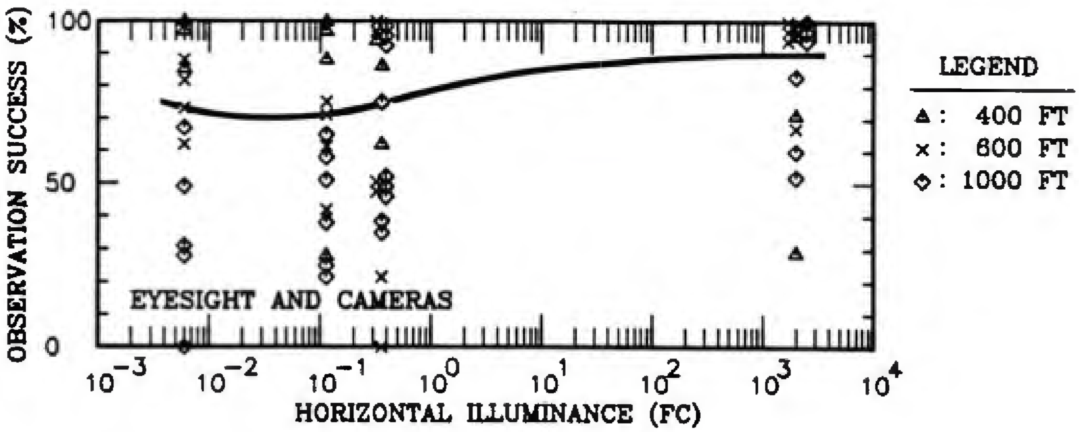

Figure 4.57. Observation of swimmer versus lighting.

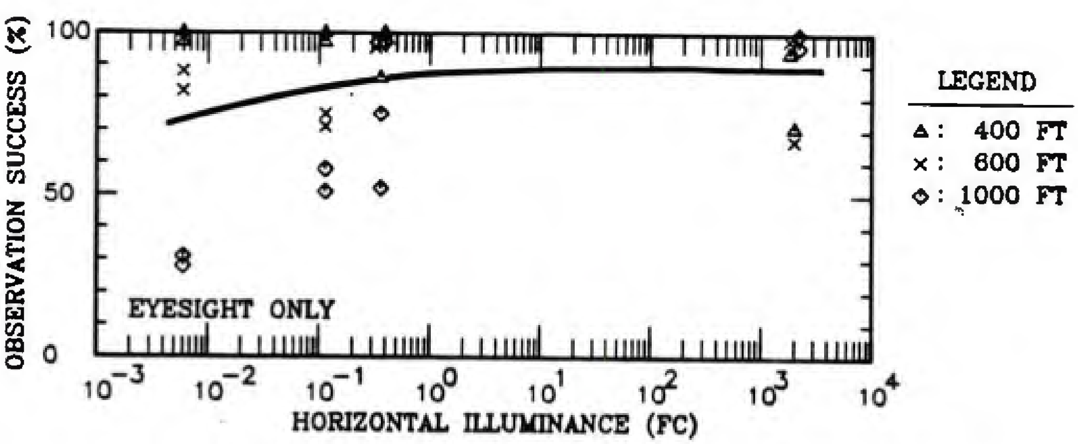

Figure 4.58. Human observation of swimmer versus lighting.

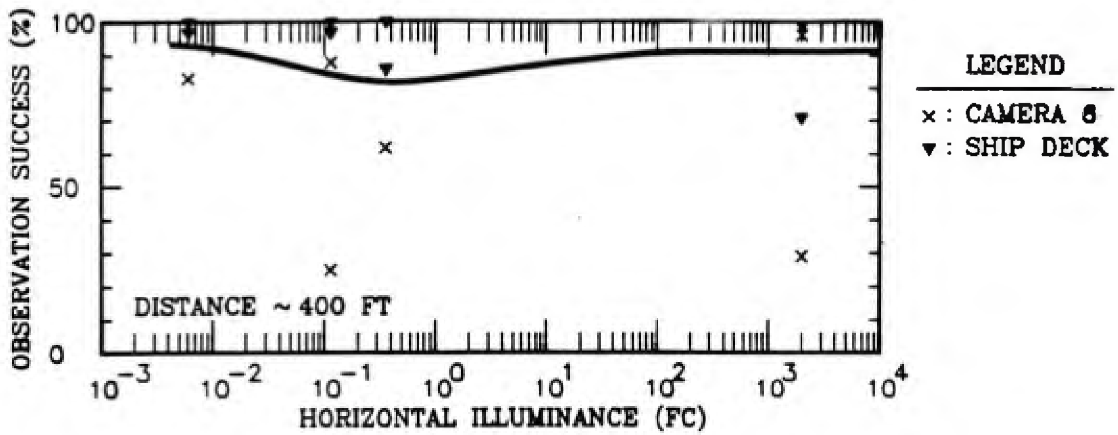

Figure 4.59. Swimmer observation success versus lighting from 400 feet.

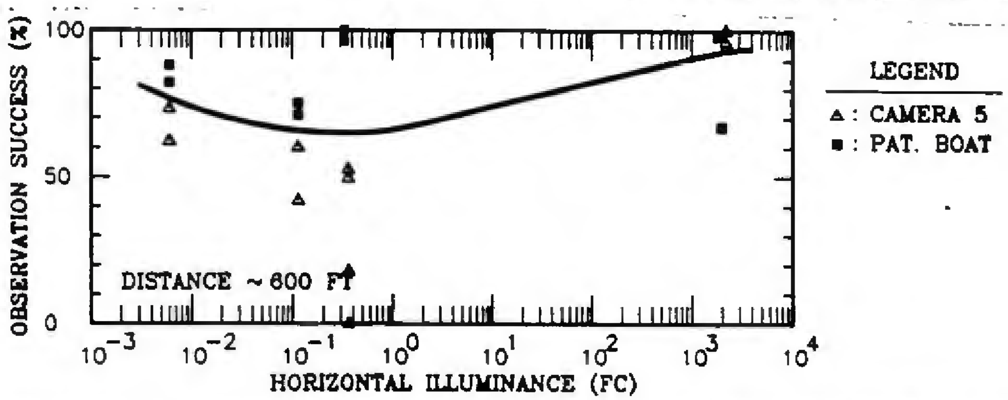

Figure 4.60. Swimmer observation success versus lighting from 600 feet.

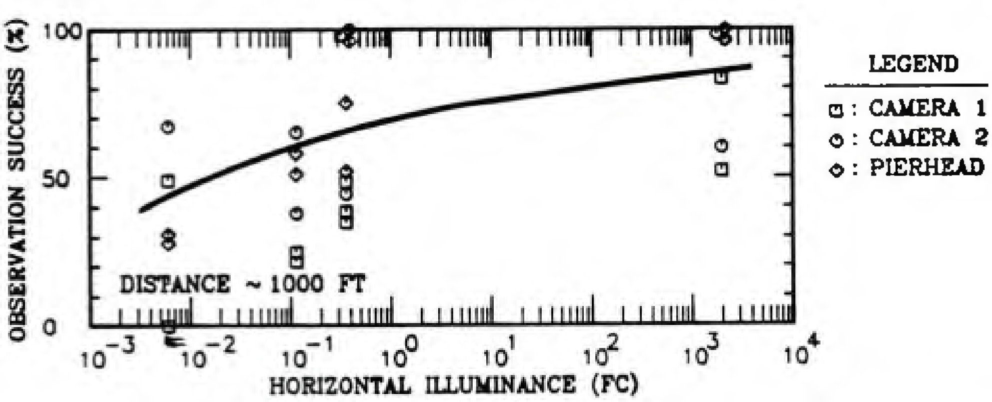

Figure 4.61. Swimmer observation success versus lighting from 1000 feet.

fields of view to the proper overlapping zone of intrusion activity. The human observer scores were excellent even in the dark if distance was within 600 feet.

4.6.4 Threat tactics

Examination of data for zodiac movements on the water indicate that almost ideal observability exists in all lighting conditions, even the dark. A single observer or camera at any location should provide satisfactory security in any lighting if the intruders use a boat.

4.6.5 Glare

There is inconclusive evidence that the lighting system reduces visibility on the water due to glare.

4.7 PIER OPERATIONS

Considerable effort was devoted to obtaining detailed quantitative data regarding the effect of various lighting levels upon efficiency of normal night pier operational procedures.

Night pier operations are not performed on a continuing basis. Instead, peaks of "high tempo" pier operations occur a few times per year that include night loading activities. Very few night arrivals or departures of ships occur due to consideration of seamanship and work schedules of shoreside personnel. When such mooring operations do occur, they occur without warning and do not allow time for introducing an observer to the pier in order to record data. Even if there were sufficient time to call observer personnel to the pier for a ship arrival, this would be highly undesirable, since it would be obvious to the personnel performing their operational duties and would likely affect their performance. These problems were avoided by placing a CCTV system on the pier to video record the operational activities over long periods. This system was installed long before the data was recorded in order to acclimate personnel to their presence.

The CCTV system consisted of four cameras mounted close to the top of the prototype lighting system 100 foot poles and the associated video recording equipment in a van on the quaywall. The video recording equipment multiplexed the signals from

from the four cameras, performed timelaps recording with annotated date and time information, and allowed for high speed replay. This equipment was left in a continuous passive record mode for over one month to record ship berthing operations at night in various lighting conditions. This allows comparison among day, dark, and floodlit conditions of specific timelines for; mooring, brow placement, and utility hookups. Previous work is reported in the document "Port Systems Project Pier Utilization Study for Small and Medium Surface Combatants" produced for the Navy Civil Engineering Laboratory.

Information available in this report was examined and the following conclusions drawn that provide a point of departure for the pier operational passive data recording phases of the test. In daylight at NAVSTA San Diego, the average of a number of ship berthing required 29.4 minutes to fix all lines and place the brow. Personnel count involved in the arrivals were 15.3 of the ships crew and 9.45 of the shoreside personnel. Departures averaged 23.2 minutes, utilized 13.8 crew and 9.8 shore personnel. Similar data from NAVSTA Norfolk showed arrivals occurring in 25.5 minutes using 38.5 crew and 9.8 shore personnel. Brow placement upon arrival averaged 15 minutes of this time, while upon departure the brow consumed 18 minutes of activity directly. This report also provided much daylight information upon the time consumed in utility connections. Typically, all utilities were connected within an average of 57.7 minutes, using a reported 31.3 man hours (around 30 people). Departure utility actions totaled 27.1 minutes and 15.0 man hours (again around 30 people). Separate timelines were reported for electrical, steam, water, telephone and CHT connections, with a factor of 4 variance.

This test for pier operations data recording did not occur because of the absence of night ship berthing operations. No night arrivals or departures of ships at pier 5 occurred between December 9, 1988 and January 15, 1989. Therefore, the quantitative comparison of lighting related pier performance timelines cannot be provides.

Upon recognition of this fact on January 16, discussions centered upon whether to"stage" a couple of berthing to obtain data,or to call observers to the site when one occurred normally. Both these approaches were deemed impractical. Staging berthing would likely produce tainted and untrustworthy data because word of the reason would leak out causing personnel to optimize their performance. Calling an observer when a random arrival finally occurs was ruled out because of short warning intervals and base security. Finally, use of the prototype lighting system after January 15 was prohibited by expiration of test permits to allow operation of the lighting system.

In the absence of the desired quantitative data, the following useful information is offered. During night active security tests, two ship arrivals were witnessed at pier 5 by the test team. Also, during a 1987 site familiarization tour a night, another arrival was witnessed. The test team did not therefor suspect that there would be an absence of data during passive pier operations recording and did not interrupt other pressing duties to record in detail the operations data. They did however record certain gross timeline data in passing with the intent to add it to the eventual data base.

During the site familiarization trip the berthing required only around 15 minutes in order to tie up and set the brow. The crane was used to help with the electrical connections and performed this within 15 minutes to one half hour with some darkness influenced difficulty. This operation was performed in the dark before the lights were operational.

On December 1, the USS Lang arrived on the starboard side of pier five (looking out) nearest the quaywall. The arrival began at 1820. Lines were out by 1824. The crane departed the pier by 1837. It therefore took less than 15 minutes to tie up and place the brow. This operation was performed in the low intensity "glare lighting" configuration with approximately 2 foot-candles illuminance of the pier surface.

On December 7, the USS Rentz arrives at 1410 in daylight. Bow lines are secure at 1435. Brow placement begins at 1443. All lines are secure at 1444. The brow is in place at 1453.

Therefore, in daylight, berthing operations are not discernably faster than in the dark or floodlit conditions.

Both night arrivals were performed more efficiently than the single day arrival noted here or the average of the day arrivals documented in the previous works. Night crane operations witnessed by the test team were regarded as extremely efficient. The two man crane team used hand signals and a spotlight on the tip of the crane to minimize their work time. It should be noted that their motivation for efficiency at night is quite high, since these crane personnel are called out of off duty time to perform this work. These crane personnel are the same ones on duty all day.

Another qualitative observation is warranted based upon our inspection of pier operations. Efficiency of timelines is not necessarily the primary justification for lighting. Many inefficiencies are built into the system of standard practices that result from the relatively large number of personnel that are needed in order to support wartime activity. Since the personnel inventory is determined by wartime needs, both shipboard and shoreside, a surplus often exists for normal peacetime operations. This results in a different trade-off in procedures than in the civilian economic based situation. Navy operations are not necessarily based upon minimizing labor content in order to cut cost. A case in point exists in crane operations. The crane often arrives on the pier to support daylight berthing operation an hour before the ship arrives. This is either due to the lack of other duties for the crane over this period or due to the arrival of the ship after its scheduled time. The point is that cutting the interval required for brow placement by 5 minutes (a significant one-third saving) will only cut the crane time devoted to the berthing by 5 to 10 percent. The natural tendency to be quick at night when the time is coming out of one's time-off appears to be more important than the lighting level.

These observations are at odds with the uniformly positive comments offered unsolicited by ships' officers, ships' crew, shoreside pier utility workers, and others. All commented that the lights were of great benefit to their performance both on the pier surface and on the ships' decks. No negative comments were even recorded regarding the effect of glare on berthing operations from the water.

The data regarding value of lighting to pier operations is still inconclusive. Whether to light may not even be a subject dominated by the normal peacetime pier operations requirements. It may instead be a subject dominated by wartime loadout timeline requirements.

4.8 PIER SAFETY

During nearly two months of pier recording, no accident of significance was evident to the test team. This was not unexpected, since no history of significant safety problems exists for Navy piers.

This comment does not ignore the fact that severe injuries and deaths have occurred on Navy piers. Such data has been made available to the test team. A number of such accidents have pointed toward inferior lighting as a "contributing" effect. However, normalizing data regarding the relative number of daytime accidents was not available for performing statistical analyses of the importance of lighting. Many other factors besides lighting are of obvious importance, including; alcohol, absence of construction barricades, and pedestrian traffic completely intermingled with traffic including heavy equipment and overhead crane operations.

It is clear that the safety risk is high on the piers and that the high level of training and care on the part of most personnel is a major reason for low or acceptable accident rates. The civil sector would not condone pedestrian traffic in the middle of a street or construction project. The yellow and red stripes painted along the pier to define a pedestrian walkway are faded out, unenforced and ineffective at separating foot traffic from vehicular traffic including cranes and dumpsters. Even yellow plastic crowd control tape and traffic cones would seem a minimum requirement in similar civil sector situations. Application of yellow painted crosshatch to the surface of a designated walkway would also seem constructive, whether instead of or in addition to night lighting. There is significant doubt as to whether the greater safety risk for Navy piers is during the very high traffic periods of daylight as compared with night. The high day traffic density on the test pier tended to obscure even vision down the length of the pier, while at night this was not a problem.

Subjectively, the test team felt "comfortable" in the darkness with only ambient lighting. They also felt that light as low as 1 foot-candle was quite sufficient for easy movement on the pier. Greater light levels may be of great help to operations personnel working with small, written or dangerous (high voltage) objects. Insufficient data exists to quantify such factors.

SECTION 5

DELPHI SURVEY

5.1 INTRODUCTION

As part of this study a Delphi Survey of a panel of Navy experts was conducted. The Delphi Survey is a formal technique for eliciting and refining group judgments. The objective of applying this Survey Technique to the Pier Lighting Project was to identify important considerations related to lighting specifications for Navy piers considering pier security, operations and safety. The panel of experts assembled for this purpose represented a broad spectrum of related knowledge and experience and included:

1. Mr. James V. Culpeper
   Head Occupational Safety Shore Programs
   Naval Safety Center
   Code 41
   Naval Air Station
   Norfolk, VA 23511-5796

2. Mr. Kevin F. Kenworthy (Code 24X21C)
   Naval Security and Investigative Command
   4600 Silverhill Rd.
   Washington, D.C. 20388-5400

3. Dr. Al Harabedian
   Naval Ocean Systems Center
   Code 445 (Barracks Bldg. 344)
   San Diego, CA 92152-500

4. Chief R. C. Warner
   32nd Street Naval Station
   Waterfront Operations, Code 98
   P.O. Box 116
   San Diego, Ca 92136

The Delphi Survey methodology is reviewed in Sections 5.2 and the results of the survey in Section 5.3.

5.2 DELPHI SURVEY METHODOLOGY

5.2.1 Introduction

Section 5.2.2 provides an overview of the Delphi Survey process followed in Section 5.2.3 with its inherent problems and limitations.

5.2.2 The Delphi Survey Process

In general a Delphi Survey is most appropriate in situations where because of the inherent nature of the problem and/or because of limited resources, it is not possible to *quantitatively* establish objective and measurable relationships between the various factors effecting a problem area. In such situations one must rely on the judgement of experts who are familiar with and who have dealt with the various aspects of the problem.

The distinguishing features of the Delphi Survey are:

1. Anonymous response of a Panel of experts to a formal questionnaire.
2. Iteration and controlled feedback.
3. Statistical presentation of the results.

A Delphi Survey is carried out by individually interrogating a Panel of experts using a series of formal questionnaires. To reduce the influence of such things as dominating personalities and distinctions of job rank it is important that individual answers provided to the questions remain anonymous.

"Iteration and controlled feedback" means the individual members of the Panel have the opportunity to review how the Panel *as a whole* has responded to the questions and to modify their own answers considering the group opinion. This means a series of successive questionnaires (where any one submittal is referred to as a "round") which is continued until the group opinion has stabilized.

"Statistical results" means the questionnaire itself is designed in such a way that it allows each answer to be readily analyzed on a statistical basis to quantitatively reflect the group opinion. One approach to accomplishing this is that, whenever possible, the question is designed to allow a selection from a series of multiple choice answers. The individual Panel member is then instructed to rank the answer provided as to relative importance. In assigning rank numbers, "1" means the highest rank, "2" the next highest, etc.

The "classic" or "pure" Delphi Survey is composed of the following steps:

1. Select a Panel of experts.
2. The Panel of experts (anonymously to each other) identify the issues of importance and a questionnaire is formulated for each major issue. If possible the questionnaire takes the form of easy to understand multiple choice answers to be ranked ordered as to relative importance.
3. The resulting questionnaire is spent to the panelists (Round 1).
4. The answers received are statistically analyzed to establish weighted average rankings to each answer option reflecting the group opinion. Table 5.1 gives an example of one question from the Pier Lighting Delphi Survey and how the results of a typical round are displayed. The "Panel Rating Measure" for *each* multiple choice answer is obtained using the equation

$$R = \frac{\left(\begin{smallmatrix}\text{Frequency Rank 1}\\ \text{chosen}\end{smallmatrix} \times 1\right) + \left(\begin{smallmatrix}\text{Frequency Rank 2}\\ \text{chosen}\end{smallmatrix} \times 2\right) + \cdots \left(\begin{smallmatrix}\text{Frequency Rank N}\\ \text{chosen}\end{smallmatrix} \times N\right)}{\text{Number of Panel Members Responding}} \quad (5.1)$$

5. The questions and analysis are returned to each panelist for further consideration based upon the individual's opinion versus the group opinion (Round 2).
6. Steps 4 and 5 are repeated as necessary until there is stabilization of the group opinion (Round 3). This means that the Panel Rating Measure (R) for each question is not changing enough between rounds to influence the Panel Rank of the question options.

5.2.3 Delphi Survey Problems and Limitations

The Delphi survey is not an answer-all technique. There are specific limitations which should be appreciated in interpreting the results of any survey.

1. It can be psychologically difficult for panelists to identify from scratch all the important issues and, hence, there is no guarantee that the questionnaire will be completely relevant to the needs of the study.
2. One or more of the panelists may *not* be a true expert on one or more of the questions, but his answers will carry equal to weight those who are.

Table 5.1. Sample Round 1 Question Results.

Average Panel Ranking						Your Ranking		
Round 3		Round 2		Round 1		Round 2		
Panel Rating	Panel Rank	Panel Rating	Panel Rank	Panel Rating	Panel Rank	Your Ranking	12.	Of the following light SPECTRUM options, which is most helpful in improving SECURITY for LIGHTS SHINING ON THE PIER.
								Please rank and explain under comments:
				1.25	1	—	—	High pressure sodium (yellow white or gold) (being tested)
				2.25	2	—	—	Low pressure sodium (yellow)
				3.00	3	—	—	Mercury vapor (blue white)
				4.50	4	—	—	Halide (car headlight)
				5.50	6	—	—	Red
				4.50	4	—	—	Infrared with eye vision enhancement equipment on men
				4.75	5	—	—	Infrared with closed circuit TV
						—	—	Other (specify)

Comments:

1. *If one has pier lighting then the two infrared options are not applicable.*
2. *Need lighting expert to determine this.*
3. *In general:*
   - *HPS is the best for pier surface cost effectiveness.*
   - *Mercury vapor is good for over water as well as metal Halide... i.e. less reflection from the water based on their blue wave length.*
   - *IR light is good for areas where there is a need for covert surveillance or limited to lights based on navigation safety.*
4. *"Best estimate" answer — people with different types of security backgrounds (security, anti-terrorist, insurance, etc.) would best be suited to answer these.*
5. *Low sodium yellow looks great does not create blindness.*

3. Panel members may be misinformed, particularly in matters outside of their areas of expertise.

4. A consensus may never be achieved on certain questions. This can simply mean that more information may be required to sway opposing views one way or another.

5. The panel can take on a life of its own – i.e., the issue of reaching agreement becomes greater in importance than producing well thought-out and useful results. For example, it is possible that a consensus can be reached that offends no one even though no one really agrees either.

6. Members of the group may have vested interests and biased points of view.

7. The whole group may share a common bias.

5.2.4 The Delphi Survey Approach As Applied to the Pier Lighting Project

The Delphi Survey Panel members (see Section 5.1) were selected to bring to this research project excellent qualifications and broad experience. Each member represents a different area of expertise within the Naval community, and each member is an expert within his field.

The following paragraphs describe the successive Delphi rounds. Examples of the material comprising each round are illustrated.

Round 1 – A questionnaire was developed with the close cooperation of each individual Delphi Panel member. As part of this process an initial draft questionnaire was developed by NCEL and MRC staff members and circulated to the Panel for review with the instructions shown in Table 5.2.

A visit was then made to the office of each Panel member by MRC personnel. During this visit, the overall content of the questionnaire was examined for completeness in addressing all the important issues and then each specific question was also reviewed for content and clarity.

Based on the Panel members input, the original draft questionnaire was expanded, reorganized and clarified. The resulting final questionnaire contained a total of 35 questions, 19 of which are security related and 16 operations and safety related. This final questionnaire is contained in Appendix A.

Table 5.2. Instructions Accompanying the Draft Preliminary Questionnaire.

PIER LIGHTING REQUIREMENTS **DELPHI SURVEY** **DRAFT** **Preliminary Questionnaire**
INSTRUCTIONS:
Attached is a preliminary questionnaire for the Delphi Survey. At this time do *not* complete the questionnaire but simply review the questions for completeness and accuracy. Ask yourself the following:
1. Do these questions address all the important issues of significance to you? If not, add a short description of additional issue that should be addressed on the next page. 2. Is any of the indicated questions unclear or confusing. if so indicate which question(s) and why in the *"Comments"* section for that question. 3. Are the answer choices provided for a given question complete. if not add to them appropriately.
Your input into this questionnaire will be individually reviewed with you at your office by project members in September. We will call you to set up an appointment.
Thank you.

Once completed this questionnaire was distributed to Panel members with the instructions shown in Table 5.3 for Round 1 of the Delphi Survey.

Round 2 – Upon completion by the Panel, the individual rankings of options provided under each question for Round 1 were analyzed using Equation 5.1 to obtain a Panel Rating. Using this Panel Rating an overall Panel Ranking for each question option was established.

The Panel Rating and Group Rank was transcribed next to each question (see Table 5.1) together with any comments provided by the Panel members in the "Comment" section under each question.

A given individual's Round 1 response, along with the second round questionnaire showing the group ranking was then returned to each Panel member along with the instructions shown in Table 5.4. Each Panel member was asked to study the group reply, review his personal response and once again rank each item, based upon this review.

Round 3 – When received, the rankings of options under each question for Round 2 was analyzed again using Equation 5.1 to obtain a Round 2 Panel Rating and overall Panel Ranking.

The third round questionnaire was submitted to the Panel with the instructions shown in Table 5.5 and with a summary of the results of the lighting tests on Pier 5 at Naval Station San Diego. The questions for Round 3 were scored as in the previous rounds.

Final Results – A summary of the analysis and results of each question of the Delphi Survey is presented in the next section. Detailed results for each questions and each round of the survey are given in Appendix A.

5.3 SUMMARY OF DELPHI SURVEY RESULTS

Tables 5.6 and 5.7 summarizes the Delphi Survey results as they relate to security and safety and operations, respectively. Appendix A presents the Panel Rating and Rank for each specific Delphi Survey question option followed by a general concluding statement for each question.

In general the Delphi survey resulted in the following general conclusions:

Table 5.3. Instructions Accompanying the Round 1 Questionnaire.

PIER LIGHTING REQUIREMENTS
DELPHI SURVEY
Round 1
Preliminary Questionnaire

INSTRUCTIONS:

Attached is the Round 1 Questionnaire for the Delphi survey that incorporates the review comments of all panel members stemming from our recent visits. At this time, please complete the questionnaire and return by *October 24, 1988* to Larry Pietrzak int he envelope provided. His address is:

Larry Pietrzak
Protection Technology Systems Group Leader
MISSION RESEARCH CORPORATION
P.O. Drawer 719
Santa Barbara CA 93117

Please consider the following guidelines in answering each question:

1. Provide an order number ranking for each question based on your best judgement. In assigning rank numbers, "1" should mean the highest rank, "2" the next highest, etc.
2. It is permissible to assign the *same* rank order number to more t han one option.
3. If you feel the options provided are not complete add to them and assign ranks appropriately.
4. If you feel you do not have the experiance or knowledge to adequately rank the choices provided, please provide your *best estimate* and indicate this is an *estimate* in the *"Comments"* section as well as the *type of individual(s) you believe would be most qualified* to answer the question.
5. If more then one individual is involved in the completion of this questionnaire within your organisation, please summarise and send only one completed questionnaire with *one* set of rankings representing the consensus of opinion in your organisation.

Thank you.

Table 5.4. Instructions Accompanying the Round 2 Questionnaire.

PIER LIGHTING REQUIREMENTS
DELPHI SURVEY
Round 2

INSTRUCTIONS:

Attached is the *final* Round 2 Questionnaire for the Delphi Survey that incorporates the answers and comments of all panel members from the earlier Rounds 1 Questionnaire. Round 2 of the Delphi Survey allows you the opportunity to review how the Delphi Panel as a whole responded to each question during Round 1 of the Survey and, if desired, to modify your own answers considering the group opinion.

The Round 2 Questionnaire is identical to the Round 1 Questionnaire except in the following respects. On the left hand side next to the answer opinion given for each question are three columns of numbers. The *1st column* is the average Panel Rating for the Round 1 to the answer option by the Delphi Panel *as a whole*. This Panel Rating is based on the relative frequency individual Delphi members assigned a given rank number to a given answer option. In the 2nd column is the Round 1 Panel Rank of the given answer option based on the Panel Rating number. (Note small differences in the Rating number imply the answer options where closely ranked.) In the 3rd column is the rank *you personally* had assigned to the answer option during Round 1 of this Survey. Also in the *Comments* section below each question is a summary of any comments provided by individual panel members in support of the answers they selected during Round 1.

At this time, please complete the Round 2 Questionnaire, making any changes to your answers as necessary, and return by *December 15, 1988* to Larry Pietrzak in the envelope provided. His address is:

Larry Pietrzak
Protection Technology Systems Group Leader
MISSION RESEARCH CORPORATION
P.O. Drawer 719
Santa Barbara CA 93117

Table 5.4. Instructions Accompanying the Round 2 Questionnaire (con't).

Please consider the following guidelines in answering each question:

1. *Compare* the rank you personally assigned (i.e., the 5^{th} column number) to a given answer option against that of the Panel Rank for Round 2 (i.e., the 2^{nd} column number), and also review any comments provided under the *Comments* section of the question. *At this time* you can either keep the same rank of the answer option as you originally assigned, or if you differ with the Panel Rank and feel, after careful consideration, that the Panel rank is, in fact, more reflective of the proper rank, or if you feel you want to change your rank after reviewing the test results change your rank appropriately. *In any case please insert a rank number (either the same as before or a new number) to each answer option. Do not leave any blanks.*
2. Recall, in assigning rank numbers, "1" should mean the highest rank, "2" the next highest, etc.
3. Also recall that it is permissible to assign the *same* rank order number to more than one option.
4. If more then one individual is involved in the completion of this questionnaire within your organization, please summarize and send only one completed questionnaire with *one* set of rankings representing the consensus of opinion in your organization.

Thank you.

Table 5.5. Instructions Accompanying the Round 3 Questionnaire.

PIER LIGHTING REQUIREMENTS
DELPHI SURVEY
Round 3

INSTRUCTIONS:

Attached is the *final* Round 3 Questionnaire for the Delphi Survey that incorporates the answers and comments of all panel members from the earlier Rounds 1 & 2 Questionnaires. Enclosed also is a summary of the results of the lighting tests on Pier 5 at Naval Station San Diego. Round 3 of the Delphi Survey allows you the opportunity to review how the Delphi Panel as a whole responded to each question during Round 1 and 2 of the Survey and, if desired, to modify your own answers considering the group opinion as well as the enclosed test results.

The Round 3 Questionnaire is identical to the Round 2 Questionnaire except in the following respects. On the left hand side next to the answer opinion given for each question are two additional columns of numbers. The *1st column* is the average Panel Rating for the last Round 2 to the answer option by the Delphi Panel *as a whole*. This Panel Rating is based on the relative frequency individual Delphi members assigned a given rank number to a given answer option. In the 2nd column is the Round 2 Panel Rank of the given answer option based on the Panel Rating number. (Note small differences in the Rating number imply the answer options where closely ranked.) The next two columns are results for the Round 1 survey. In the 5th column is the rank *you personally* had assigned to the answer option during Round 2 of this Survey. Also in the *Comments* section below each question is a summary of any comments provided by individual panel members in support of the answers they selected during Round 1 and 2.

At this time, please complete the Round 3 Questionnaire, making any changes to your answers as necessary, and return to Larry Pietrzak in the envelope provided. His address is:

Larry Pietrzak
Protection Technology Systems Group Leader
MISSION RESEARCH CORPORATION
P.O. Drawer 719
Santa Barbara CA 93117

Table 5.5. Instructions Accompanying the Round 3 Questionnaire (Con't).

Please consider the following guidelines in answering each question:

1. *Compare* the rank you personally assigned (i.e., the 5th column number) to a given answer option against that of the Panel Rank for Round 2 (i.e., the 2nd column number), and also review any comments provided under the *Comments* section of the question. *At this time* you can either keep the same rank of the answer option as you originally assigned, or if you differ with the Panel Rank and feel, after careful consideration, that the Panel rank is, in fact, more reflective of the proper rank, or if you feel you want to change your rank after reviewing the test results change your rank appropriately. *In any case please insert a rank number (either the same as before or a new number) to each answer option. Do not leave any blanks.*
2. Recall, in assigning rank numbers, "1" should mean the highest rank, "2" the next highest, etc.
3. Also recall that it is permissible to assign the *same* rank order number to more than one option.
4. If more then one individual is involved in the completion of this questionnaire within your organization, please summarize and send only one completed questionnaire with *one* set of rankings representing the consensus of opinion in your organization.

Thank you.

Security Threat. The most critical pierside threat is considered the walking threat, followed by running or crawling. The more critical water threat is considered the swimmer followed by a boat.

Security Guard Observer Location. For lights located on the pier, a roving guard on the pier is preferred. For lights on the ship, a guard on the bridge of the ship; and for lights located underwater, a guard on the fantail/forecastle of the ship is preferred.

Safety/Operational Activities Improved By Lighting. Pedestrian traffic followed by crane operations are the pierside activities be most improved by lighting.

Fixture Location. The pier surface is preferred when considering both security as well as safety and operations. Security considerations also give preference to a location underwater next to the pier for water threats.

Fixture Height. For lights on the pier there is a preference for 100 ft above the pier surface. This is the case considering both security as well as safety and operations.

Pole Spacing. 630 ft is preferred considering security, operations and safety factors.

Amount of Lighted Area. For lights shining on the pier, all of the pier surface is preferred when considering security, safety and operational factors. For lights shinning on the water, the full surface of the water between the piers is preferred.

Light Intensity. 2 ft-candles is preferred as a balance security, safety and operational factors.

Time Lights Are On. 100% is preferred for security. Up to 10% is indicated for most operational activities with the exception of vehicle transport and pedestrian traffic where 50% of the time is indicated.

Spectrum Options. High pressure sodium is preferred under all conditions.

Pier Surface Reflectivity. Intermittent beaded stripes of retro- reflectors across the pier (i.e., like highway lane dividers) is the first choice for security, with gray as a second choice. Gray is preferred for safety and operations.

Table 5.6. Summary of Delphi Survey Results Related to Security.

ATTRIBUTE	PANEL PREFERENCE FIRST CHOICE	SECOND CHOICE	DELPHI QUESTION NO.
1. THREAT			
• PIER	WALKING	RUNNING OR CRAWLING	1
• WATER	SWIMMING	BOAT	1
2. FIXTURE LOCATION	PIER SURFACE	UNDERWATER NEXT TO PIER	2
3. OBSERVER LOCATION			
• LIGHTS ON PIER	ROVING ON PIER	TOWER MOUNTED CCTV	3
• LIGHTS ON SHIP	BRIDGE OF SHIP	MAN ON QUARTERDECK OF SHIP	4
• LIGHTS UNDERWATER	FANTAIL/ FORECASTLE OF SHIP	ROVING PATROL ON SHIP	5
4. FIXTURE HEIGHT FOR LIGHTS ON PIER			
• LIGHTS SHINING ON PIER	100 FT	75 FT	15
• LIGHTS SHINING ON WATER	100 FT	75 FT OR UNDERWATER	16
5. POLE SPACING FOR LIGHTS ON PIER	630 FT	315 FT	17
6. AMOUNT OF LIGHTED AREA FOR FIXTURES LOCATED ON PIER			
• SHINING ON PIER	ENTIRE PIER	INTERMITTENT LIMITED SIZE SPOTS ALONG PIER EDGE (e.g., LIKE RUNWAY LIGHTS)	6
• SHINING ON WATER	WATER BETWEEN TWO PIERS	LIMITED AREA OF WATER	7

Table 5.6. Summary of Delphi Survey Results Related to Security.

ATTRIBUTE	PANEL PREFERENCE FIRST CHOICE	PANEL PREFERENCE SECOND CHOICE	DELPHI QUESTION NO.
7. LIGHT INTENSITY FOR PIER SURFACE			
• UNAIDED OBSERVER	2 FT-CANDLES (STREETLIGHT)	0.01 FT-CANDLES (FULL MOON)	8
• AIDED WITH CCTV	2 FT-CANDLES (STREETLIGHT)	0.01 FT-CANDLES (FULL MOON)	9
8. LIGHT INTENSITY FOR WATER SURFACE (UNAIDED OBSERVER)	2 FT-CANDLES (STREETLIGHT)	0.,01 FT-CANDLES (FULL MOON)	10
9. TIME LIGHTS ARE ON	100%	DIRECTED SPOT LIGHT AS NEEDED	11
10. SPECTRUM OPTIONS			
• SHINING ON PIER	HIGH PRESSURE SODIUM	LOW PRESSURE SODIUM	12
• SHINING ON WATER	HIGH PRESSURE SODIUM	MERCURY VAPOR	13
- CONSIDERING REFLEXIVITY	HIGH PRESSURE SODIUM	LOW PRESSURE SODIUM	19
• ENHANCED FOG PENETRATION	LOW PRESSURE SODIUM	HIGH PRESSURE SODIUM	14
11. PIER SURFACE REFLECTIVITY	INTERMITTENT BEADED STRIPS OF RETRO-REFLECTORS ACROSS PIER (e.g. LIKE HIGHWAY LANE DIVIDERS)	GRAY	18

Table 5.7. Summary of Delphi Survey Results Related to Safety and Operations.

ATTRIBUTE	PANEL PREFERENCE		DELPHI
	FIRST CHOICE	SECOND CHOICE	QUESTION NO.
1. PIER ACTIVITIES IMPROVED BY LIGHTING	PEDESTRIAN TRAFFIC	CRANE OPERATIONS	20
2. % OF NIGHTTIME HOURS FOR A TYPICAL MONTH LIGHTS LIKELY TO BE USED			
• UTILITY HOOKUP/ BROW PLACEMENT	LESS THAN 5% OR 5% TO 10%	10% to 50%	25
• CRANE OPERATIONS	LESS THAN 5%	5% TO 10%	26
• CARGO LOADING/ UNLOADING	LESS THAN 5%	5% to 10%	27
• VEHICLE TRANSPORT AND PEDESTRIAN TRAFFIC	10% TO 50%	5% TO 10%	28
3. FIXTURE HEIGHT FOR LIGHTS ON PIER			
• VEHICLE TRANSPORT AND PEDESTRIAN TRAFFIC	100 FT	75 FT	32
• OTHER ACTIVITIES	100 ft	75 ft	31

Table 5.7. Summary of Delphi Survey Results Related to Safety and Operations.

ATTRIBUTE	PANEL PREFERENCE FIRST CHOICE	SECOND CHOICE	DELPHI QUESTION NO.
4. POLE SPACING FOR LIGHTS ON PIER			
• VEHICLE TRANSPORT AND PEDESTRIAN TRAFFIC	630 ft	315 ft	34
• OTHER ACTIVITIES	630 ft	315 ft	33
5. AMOUNT OF LIGHTED AREA	100% OF PIER	LIMITED AREA OF PIER	21
6. LIGHT INTENSITY			
• VEHICLE TRANSPORT AND PEDESTRIAN TRAFFIC	2 ft.-CANDLES (STREET LIGHT)	20 ft-CANDLES (BRIGHT ROOM LIGHT)	23
• OTHER ACTIVITIES	2 ft-CANDLES (STREET LIGHT)	20 ft-CANDLES (BRIGHT ROOM LIGHT)	22
7. SPECTRUM OPTIONS			
• NORMAL OPERATIONS	HIGH PRESSURE SODIUM	LOW PRESSURE SODIUM	29
• ENHANCED FOG PENETRATION	HIGH PRESSURE SODIUM	LOW PRESSURE SODIUM	30
8. PIER SURFACE REFLEXITVITY	GRAY	YELLOW	35

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SECTION 6

INTERPRETATION OF PROGRAM RESULTS

This section concentrates upon interpreting the data into conclusions and recommendations. Some duplication of data presented earlier occurs in order to limit looking up information in previous sections. When conclusive information is unavailable, the text will attempt to explore alternative approaches for future discussion.

6.1 CURRENT SECURITY

Currently, pier security is dependent upon a single guard inspecting identification at the pier head and a roving patrol along the pier surface. Additionally, each ships' access is controlled by the quarterdeck OD. A police boat patrols the channel of the ends of the piers during the day in order to control the water surface and provide rapid response to alarm.

6.1.1 Viewing Aspect

With the exception of the roving patrol, none of these existing personnel are charged with securing the pier surface from intrusion. The test has obtained data suggesting that none of these personnel has a real chance of observing an intrusion on the surface of the pier or on the water surface prior to pier access. All of the existing security personnel are located in the wrong position to reliably observe pier intrusion either in daylight or at night in the dark.

The guard located at the pier head is distracted by badge inspection procedures, too far from the end of the pier, and faces too much daytime traffic to provide even a 25 percent chance of seeing a pier intrusion during the day. At night, without lighting, a 50 percent chance of observing is the best that can be expected.

The roving patrol is either too far from the intrusion, has his back to the intrusion, or is traffic obscured for a significant fraction of the time. The single roving patrol cannot be counted upon to be in the right place at the right time to observe a threat.

The ships' quarterdeck is by far the best location of those in current use to observe an intrusion on the pier, due to its elevated position above the traffic and its proximity to the target of a threat. The only difficulty with this location is the current lack of a stated responsibility.

The police boat cannot be expected to be able to see swimmers in the water reliably beyond 1000 feet. It would take 4 to 6 police boats continuously patrolling in order for primary detection responsibility to be assigned to these craft when there are 13 piers.

Test data suggests that the primary two variables in observing intrusions on the pier or the water are the viewing distance and the viewing aspect. The third level influence may be lighting intensity. That the first priority is viewing distance, is evidenced by the fact that no satisfactory results were obtained for viewing distances over 1000 feet and all situations under 600 feet were satisfactory. The viewing aspect is critical, especially in daylight in order to avoid traffic and glare obscuration. When sufficient numbers of guard observer personnel are pressed into service and located close enough and/or high enough to see the surface threatened with intrusion, daytime security will at least not be the limiting situation. In fact, it is quite plausible to create daytime visibility of rolling intruders above 80 percent. The difficulty might be in distinguishing a walfing intruder from an authorized person. Also, visibility is not the whole issue - guard attentiveness almost always limits and enforcement firepower is also an issue.

6.1.2 Day Time Pier Security

Daytime security visibility is limited primarily by the intense traffic, secondarily by sun glare, and finally by the length of the pier.

Traffic impacts on visibility are dependent upon where cranes and trucks operate along the length of the pier, and how long they perform their tasks. Pedestrian traffic causes some relatively minor obscuration also. Test data shows traffic caused a loss of 19% to 39% of data from direct eyesight observation at the head of the pier. It also showed 57% traffic loss using Camera 2 (next to the eyeball observer at the head of the pier) for the same intrusion period. The difference is related to the human observer moving around in order to try to see around obstacles. Glare off the pier surface caused by the low and setting sun also caused a 35% glare data loss from Camera 2 due to dynamic range limitations. When traffic or glare did not interfere, observers could only detect one of seventeen rolling intrusions at a range of 1200 feet in daylight.

Figure 6.1 shows the maximum visibility of Pier 5 in the daylight due to traffic interference as a function of viewing angle. It shows that raising the viewing angle to around 20 degrees eliminates traffic obscuration problems. Viewing angles of 10 to 20 degrees result for cameras or personnel at a height of 100 feet looking at the horizontal surface a distance of 300 to 600 feet away.

From this data one can conclude that high viewing aspects are crucial to pier security if the observer is required to look over large distances along the pier. If the observer is looking across the pier or is only guarding 50 to 150 feet, the traffic problem can be surmounted without high viewing aspects.

Figure 6.2 shows the effectiveness of observing the pier surface in clear daylight after traffic effects are removed. Specifically, Figure 6.2 gives the scatter of detection success data (in%) as a function of observer distance, and a graphical curve-fit representing the average for all camera and unaided observations. Figure 6.2 is for the most stressful case of intruders rolling across the pier at various distances along the pier away from the observer. The data on this figure shows there is a wide scatter in the performance of observers, and that beyond 900 feet, even in daylight, visibility becomes very poor. The various observer locations are identified in Figure 6.3.

6.1.3 Current Pier Night Security

Tests were run at night in the dark in order to provide a baseline against which to measure the improvement caused by lighting. At night, traffic interference was generally much lower (around 4 to 8%) from the pierhead, but some nights approached the bad daytime situation with periods of 33 to 44% traffic obscuration evident. Therefore, night traffic problems offer less justification for high viewing angles than day, but do depend upon it from time to time.

Figure 6.4 shows the results of the tests which can be compared directly with the daytime data in Figure 6.2. Figure 6.4 shows an approximate 50% detection success rate for rolling intruders almost independent of the distance up to 1200 feet. This data is obtained at illuminance of 0.005, 0.04, and 0.2 foot-candles. This night data is below the daytime data at distances below 900 feet and above daytime data at 1200 feet (probably due to lower levels of traffic obscuration).

This is shown more clearly in Figure 6.5 which compares the bounding

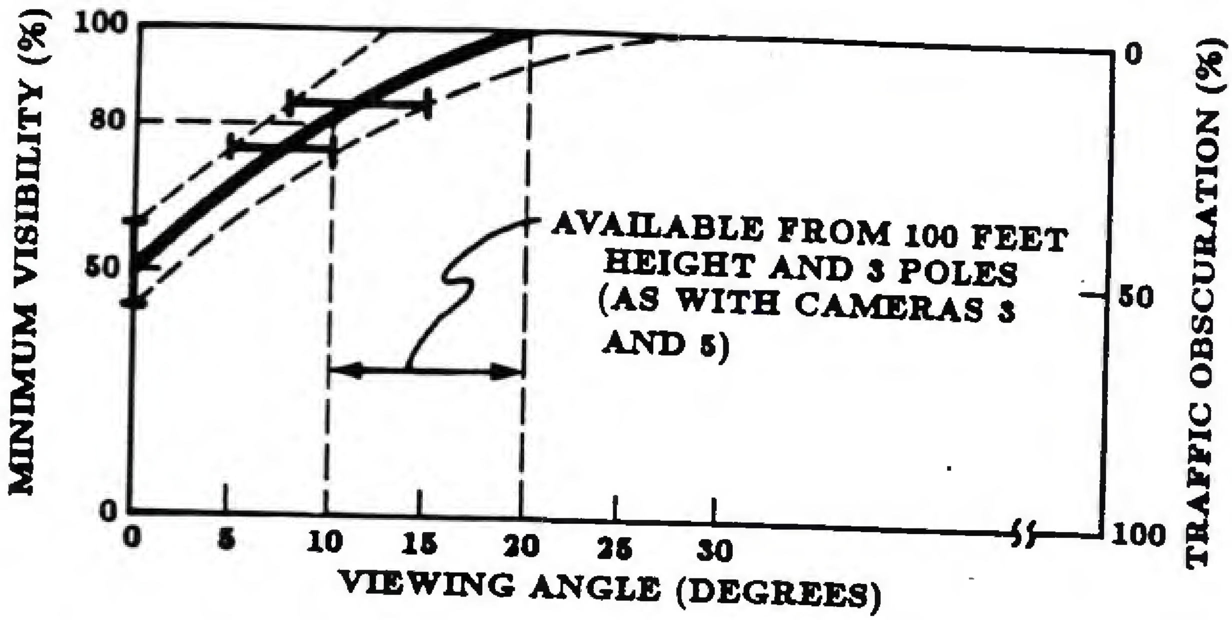

Figure 6.1. Effect of Observer Height on Traffic.

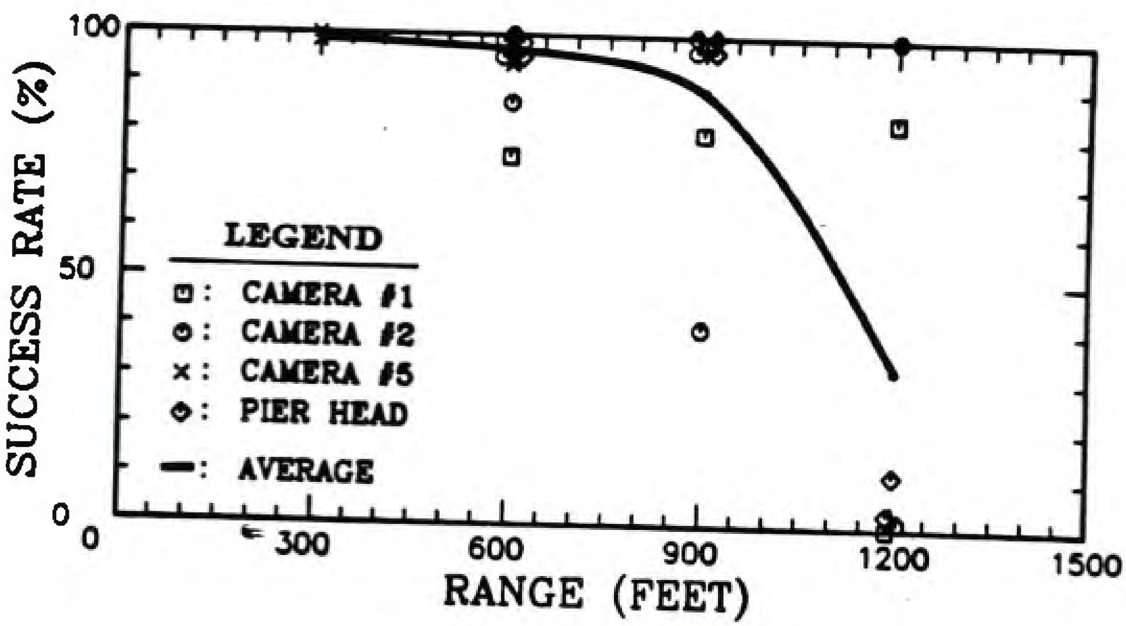

Figure 6.2. Daylight Distance Effects.

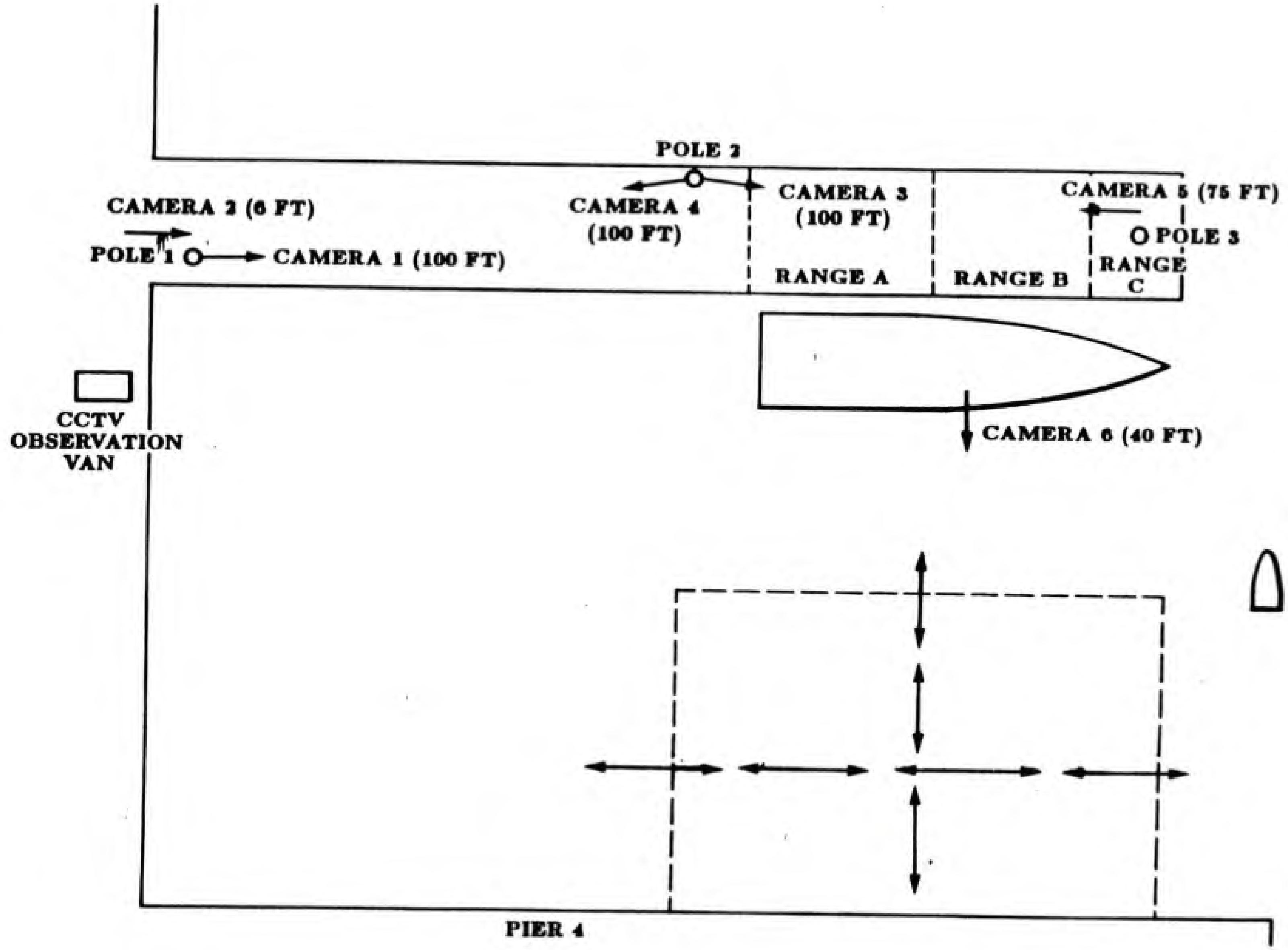

Figure 6.3. Test Site Layout.

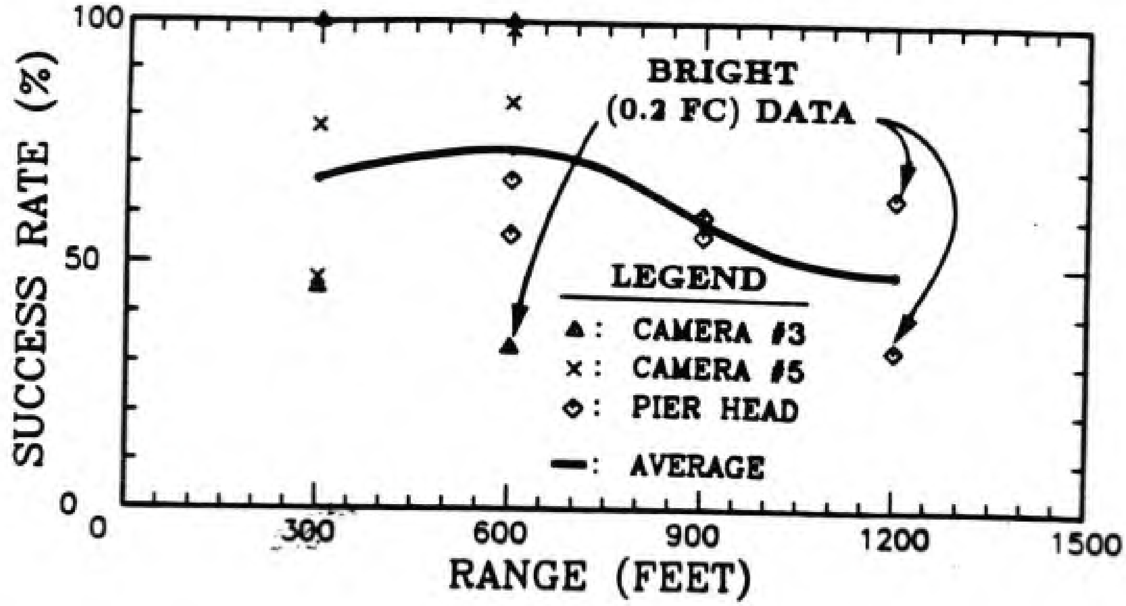

Figure 6.4. Results During Darkness.

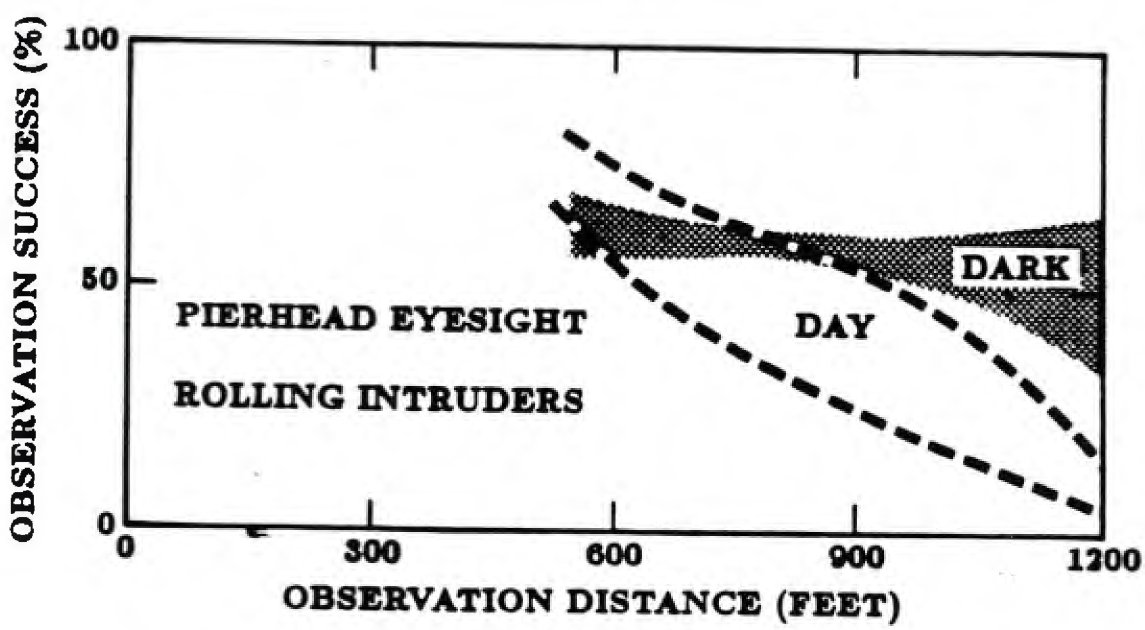

Figure 6.5. Current Security.

day and dark detection success percentages accounting for traffic obscuration effects resulting from human observers located at the head of the pier. The combination of traffic and distance cause the day results to plot below those of darkness. This raises questions as to the benefits of improving night lighting, unless day security is improved by moving the observer to higher locations to avoid traffic interference.

6.2 LIGHTING INTENSITY

Figure 6.6 compares the success at observing rolling intruders from three different observation stations. Shown is the scatter of data and average plots of observation success versus pier lighting illuminance levels, for 600, 900 and 1200 foot distances both unaided and with camera aid.

Examination of the Pierhead Eyesight Plot(B) shows that at 600 feet lighting as low as 0.03 foot-candles provides observation success in excess of 50%. At 900 feet, somewhat more light is needed for equivalent performance (about 0.1 foot candles). However, at 1200 feet distance, lighting to 2 foot-candles or greater is needed to achieve a similar performance. It is intriguing that in daylight (i.e.,100 foot candles or more) at 1200 foot distance, performance is quite poor (due to traffic obscuration).

Comparing the Camera 1 data (A), from a higher vantage point of 100 feet indicates again that at 600 feet, the lighting from 2 foot-candles provides as good performance as full daylight. However, at 900 feet, a strong sensitivity to lighting intensity is evident, with the maximum benefit also achieved in the 2 foot-candle range. Again, visibility seems to degrade at long range in daylight.

Camera 2 (C) shows less sensitivity to light, perhaps due to its magnification resulting from its 75mm lens (compared to 50mm of Camera 1). Camera 2 shows worse performance at 1200 foot distance than the human observer at moderate lighting levels, but does not do as poorly in daylight.

In aggregate, the data of Figure 6.6 suggests that at 600 feet, eye and camera resolution is sufficient that visibility is good at light levels somewhere around 0.1 and 0.3 foot-candles. At 900 foot distance, eyesight is becoming marginal and very sensitive to the lighting. Levels around 1 to 2 foot-candles appear to provide maximum performance. At 1200 foot distance, eyesight is apparently poor enough that variances among observers cannot be minimized by increasing lighting. At 1200 feet, it may be true that no amount of lighting will provide dependable observer performance.

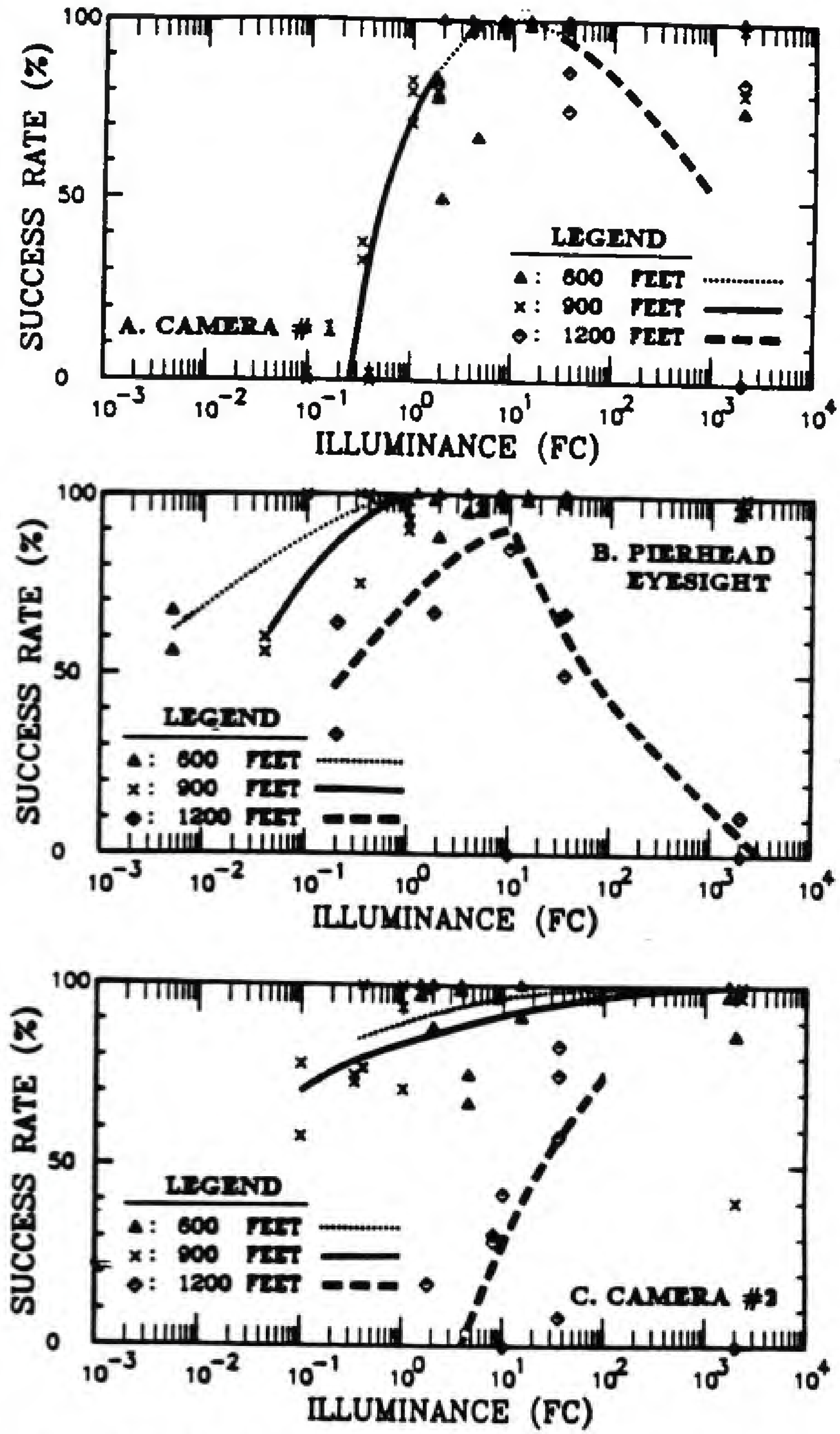

Figure 6.6. **Effects of Lighting Level and Observation Station.**

6.3 TESTED LIGHTING SYSTEM

The tested lighting system possessed most of the desirable characteristics of a pier-borne system.

6.3.1 Pole Height

The height of 100 feet is of relatively great importance in illuminating the water, because it allows shining over many of the smaller combatant moored ships. If the only objective was to illuminate the pier, and the glare lighting concept tested on December 1 were acceptable, then perhaps 50 foot high poles would be permissible. Greater numbers of shorter poles would seriously interfere with pier operations.

6.3.2 Luminaires

High Pressure Sodium (HPS) lamps used in the test are quite acceptable for all pier applications.

6.3.3 Power

The tested lighting system was well designed for the purposes of the ability to test useful lighting conditions. However, test results suggest that an operational lighting system might use fewer lamps for lighting only the pier surface. As few as 16 of the 32 400 watt spots will provide sufficient pier illumination to 2 foot-candles. It may also be true that the more diffuse 4x4 spots will prove superior at limiting hot spots at the expense of energy spill over. A system designed to illuminate both the pier and the water surface on both sides of the pier would apparently need around 48 total 400 watt lamps.

6.4 SHIP MOUNTED SYSTEM

An alternative to the pier lighting system is a lighting system mounted on the moored ship. This approach avoids any concern regarding poles interfering with pier operations. It avoids the costs associated with poles tall enough to shine down on or over moored ships and the shadow on the water caused by the ship. Such an approach could treat the luminaires as transportable (moving with the ship) or erectable (remaining at the host pier for installation in the same manner as pier utility connections).

Advantages of such a system probably include greater power efficiency by placing the light source nearer the area of intrusion concern, elimination of glare by placing the observer behind the lights in the dark, and eliminating the shadow area of the ship on the water.

Disadvantages include introduction of another crane operation during berthing, wear and tear on the luminaires as a result of handling, and dark piers when only a single ship is moored.

6.5 PERSONNEL INTENSIVE SYSTEM

Naval personnel inventory is geared to the requirements of wartime action and therefore personnel are plentiful in peacetime. This suggests that application of additional personnel to security duty while moored is worth examination. Test results suggest that 2 to 4 personnel per ship may be sufficient to surveil both the pier surface and the water surface surrounding the ship. This may be performed even without lighting at night. Two personnel at fore and aft locations on the pier side of the ship would be within 600 feet of all points of interest and also be able to see around pier traffic from above and to the side of the interference. A similar two personnel on the outboard side would be capable of surveilling the water surface. Properly stationed, these personnel could perhaps even detect divers emerging from the water along the ship's hull.

This type of security could be augmented with passive infrared glasses or even an active infrared spotlight.

6.6 PIER SURFACE CONTROL

If night security were demonstrably inferior to that in daylight, introduction of surface treatments for the pier surface would offer promise of increased visibility with lower incident light. Research performed for the US Army MERADCOM, has shown the positive effects of reflective paint, tape and highway retroreflectors. Applications to the Navy pier situation could include alternate diagonal stripes of black and reflective yellow to assure visibility of any intruder. Perhaps this treatment could even reduce daytime glare.

Such treatment may relate strongly to pier operations and safety also. All utility connections might be treated with the reflective material to help them stand out. The areas for pedestrian walkways might be treated differently – either brighter or darker. Pedestrians might even be issued reflective arm bands to aid with safety and to identify authorized personnel from intruder.

6.7 WATER SURFACE

Lighting of the water surface was tested using zodiacs and swimmers. Three human observer positions and four camera locations were used to quantify visibility. The results of these tests were quite consistent with those on the pier.

Figure 6.7 shows the results of swimmer observations from the three different human observer positions. At 400 and 600 feet, success rates are high and quite insensitive to lighting levels. At 1000 feet, the results are poor and sensitive to lighting. Securing the water from the pierhead is ineffective (in the dark, 0.006 foot-candles) but quite reliable from the ship or the patrol boat.

Replotting this data as a function of distance as in Figure 6.8 confirms the sensitivity to distance.

6.8 UNDERWATER

Once the solutions to pier and surface intrusion protection are implemented, viable threats will have to choose airborne or underwater approaches. Underwater detection is a notoriously difficult problem, demanding innovative solutions. Illumination figures in some such candidate solutions. Swimming pool type sealed beam low voltage lights may be applied by either affixing to the bottom or by lowering an array below the surface at the ships' hull. Phosphors could be introduced into the water between piers if the conditions were maintained dark enough. A sensor barrier could be created between the ends of piers that turned on lights mounted on the bottom to backlight divers (and fish).

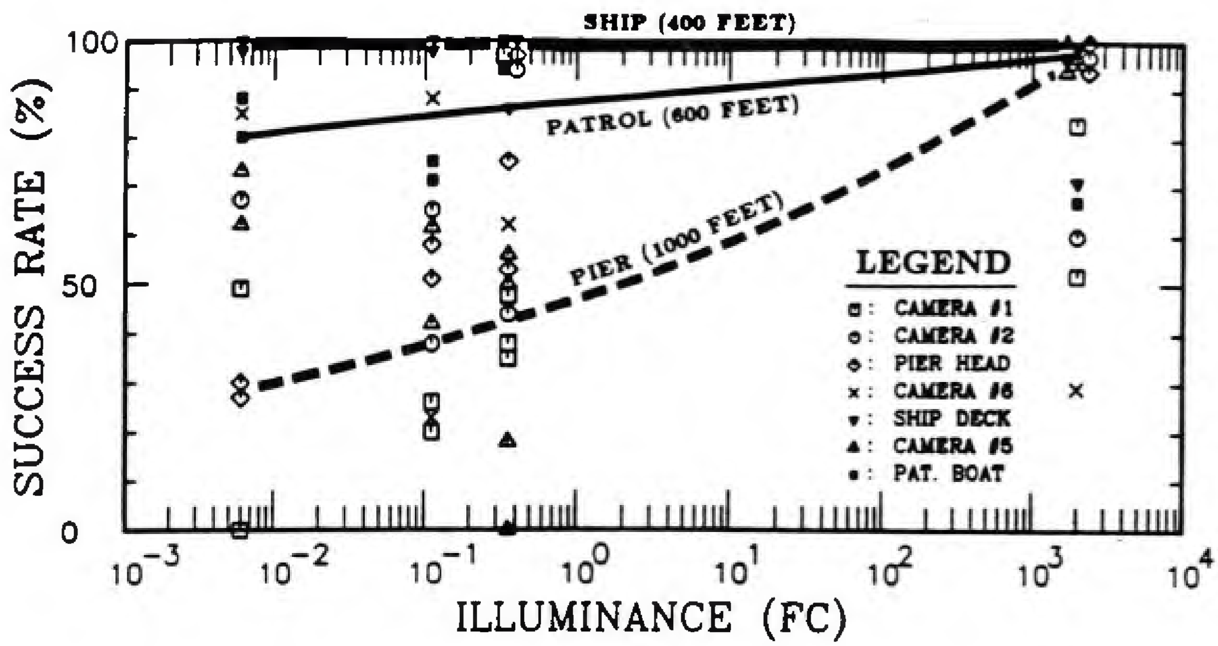

Figure 6.7. Water Test-Effects of Lighting.

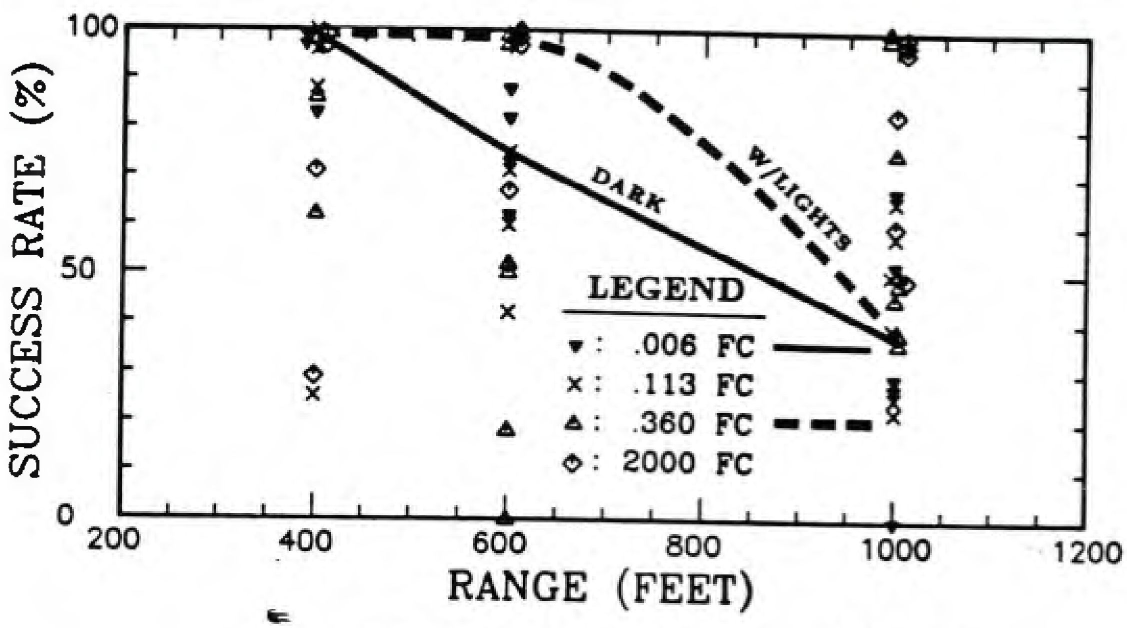

Figure 6.8. Water Test-Effective of Distance.

SECTION 7

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APPENDIX A

Detailed Delphi Survey Results

This appendix contains the detailed results of the Delphi survey. This includes the Panel Rating and rank for each question option during each round of the survey followed by a general concluding statement.

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	1. Of the following THREAT options, which is most important to provide lighting for. Please rank and explain under comments:
3.25	3	2.75	2	2.00	1	— Running (being tested) means the option indicated is being actively tested
3.25	3	3.25	4	3.25	4	— Crawling (being tested)
5.00	5	4.50	6	4.25	6	— Rolling (being tested)
3.00	2	3.00	3	2.75	2	— Walking
2.00	1	1.75	1	2.00	1	— Swimming on surface (being tested)
3.75	4	3.75	5	3.50	5	— Swimming underwater
6.75	6	6.25	7	4.75	7	— Truck
3.25	3	2.75	2	3.00	3	— Boat
7.50	7	7.25	8	6.25	8	— Aircraft
						— Other: (Specify)

CONCLUSION:

The ranking is consistent between rounds and indicates a high preference towards swimming and boat threats on the surface of the water and walking, running or crawling threats on the pier followed closely by underwater swimmers.

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	2. Of the following LIGHT FIXTURE LOCATIONS which is most helpful in improving SECURITY. Please rank and explain under comments:
1.75	1	2.00	1	1.5	1	— Pier surface (being test)
2.75	3	2.50	3	3.5	3	— Under pier
5.50	6	5.00	6	4.0	4	— Shipmast (fixed or Portable lights)
4.75	5	4.50	5	4.25	5	— Ship gunwale
2.00	2	2.25	2	3.0	2	— Underwater next to pier
3.25	4	3.00	4	3.5	3	— Underwater outboard of ship
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds and indicates a high approximately equal preference to light fixtures located on the pier surface, underwater next to the pier and under the pier.

Average Panel Ranking

3. **Of the following OBSERVER LOCATION options relative to lights located on the PIER, which is most helpful in improving SECURITY.**
Please rank and explain under comments:

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	Option
4.25	4	1.25	1	1.75	1	— Man at fixed location at end of pier
4.50	5	3.75	3	3.00	4	— Man in tower at end of pier
2.50	1	2.25	2	2.50	2	— Roving patrol on pier
4.50	5	4.50	4	3.50	5	— Roving patrol on ship
3.50	2	3.75	3	2.75	3	— Tower mounted closed circuit TV
4.00	3	5.75	5	4.50	7	— Man on quarterdeck of ship
4.75	6	5.75	5	4.00	6	— Man on bridge of ship
4.50	5	6.25	6	5.00	8	— Man on fantail/forecastle of ship
						— Other (specify)

CONCLUSION:

The ranking changes somewhat between rounds indicating in the final round a clear preference to a roving patrol on the pier, followed by tower mounted CCTV'S with the rest of the options about equally ranked.

Average Panel Ranking

4. **Of the following OBSERVER LOCATION options relative to lights located on the SHIP, which is most helpful in improving SECURITY.**

Please rank and explain under comments:

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	Option
5.00	6	2.25	1	2.50	1	— Man at fixed location at end of pier
4.75	5	4.00	6	3.25	3	— Man in tower at end of pier
3.25	2	3.25	3	3.25	3	— Roving patrol on pier
4.25	4	4.50	7	3.75	5	— Roving patrol on ship
3.50	3	3.75	5	3.00	2	— Tower mounted closed circuit TV
3.25	2	3.50	4	3.50	4	— Man on quarterdeck of ship
2.75	1	3.00	2	3.00	2	— Man on bridge of ship
4.25	4	5.50	8	5.00	6	— Man on fantail/forecastle of ship
						— Other: (Specify)

CONCLUSION:

The ranking changes considerably between rounds with a clear preference in Round 3 towards a man located on the bridge of the ship, followed by a fairly equally ranked roving patrol on the pier, man on the quarterdeck, and CCTV.

5. If the lights were located UNDERWATER which of the following OBSERVER LOCATION options is most helpful in improving SECURITY.

Please rank and explain under comments:

Average Panel Ranking

	Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank
— Man at fixed location at end of pier	7.25	8	5.75	8	4.75	6
— Man in tower at end of pier	3.75	4	3.00	4	3.75	4
— Roving patrol on pier	4.00	5	4.00	5	3.75	4
— Roving patrol on ship	2.50	2	2.50	2	3.50	3
— Tower mounted closed circuit TV	5.50	7	5.25	7	4.25	5
— Man on quarterdeck of ship	4.25	6	4.25	6	3.25	2
— Man on bridge of ship	3.25	3	2.75	3	3.25	2
— Man on fantail/forecastle of ship	1.75	1	1.75	1	3.00	1
— Other: (Specify)						

CONCLUSION:

The ranking is fairly consistent between rounds indicating a clean a preference to a man on the fantail/forecastle of ship, and a roving patrol on the ship.

6. **Of the following lighted PIER AREA options, which would most benefit from improved lighting considering SECURITY issues.**

Please rank and explain under comments:

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	Option
1.00	1	1.00	1	1.00	1	— **Entire pier (being tested)**
3.00	3	3.00	3	3.25	3	— **Limited area of pier (specify under comments)**
3.50	4	3.25	4	3.25	3	— **Movable person size spot of light on pier**
2.25	2	2.50	2	2.00	2	— **Intermittent limited size spots along edge of pier (e.g., like runway lights)**
						— **Other (specify)**

CONCLUSION:

The ranking is consistent between rounds indicting a clear preference towards the entire pier being lighted.

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	7. Of the following lighted WATER AREA options, which would most benefit from improved lighting conditions considering SECURITY issues. Please rank and explain under comments:
1.00	1	1.0	1	1.5	1	— Water between two piers (being tested)
2.00	2	2.25	2	2.25	2	— Limited area of water (specify under comments)
3.00	3	3.00	3	3.00	3	— Person size spot on water
4.00	4	3.25	4	?	?	— 200 ft. from pier and all vessels (new option specified by one panel member)
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with a clear preference towards all the water surface between the piers being lighted.

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	8. Of the following lighting INTENSITY options, which is the minimum adequate for SECURITY ON THE PIER for UNAIDED OBSERVERS. Please rank and explain under comments:
3.50	4	3.5	4	3.5	4	— Starlight (0.001 ft-candles)
2.25	2	1.75	2	2.5	2	— Full moonlight (0.01 ft-candles)(being tested)
1.25	1	1.00	1	1.0	1	— Streetlight (2 ft-candles)(being tested)
3.00	3	3.00	3	3.0	3	— Bright room light (20 ft-candles)
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with a clear preference toward streetlight intensity (2 ft-candles).

9. Of the following lighting INTENSITY options, which is the minimum adequate for SECURITY ON THE PIER for OBSERVERS AIDED BY CCTV.

Please rank and explain under comments:

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	Option
3.75	4	3.75	3	3.75	3	— Starlight (0.001 ft-candles)
1.75	2	2.25	2	2.25	2	— Full moonlight (0.01 ft-candles)(being tested)
1.25	1	1.00	1	1.00	1	— Streetlight (2 ft-candles)(being tested)
4.00	5	4.25	4	3.75	3	— Bright room light (20 ft-candles)
3.33	3	3.75	3	?	?	— Very near IR (new option specified by one panel member)
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with a clear preference towards streetlight intensity (2 ft-candles) followed closely by full moonlight (0.01 ft- candles).

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	10. Of the following lighting INTENSITY options, which is the minimum adequate for SECURITY ON THE WATER SURFACE for UNAIDED OBSERVERS. Please rank and explain under comments:
2.00	3	2.75	3	2.75	3	— Starlight (0.001 ft-candles)
1.75	2	1.75	2	1.75	2	— Full moonlight (0.01 ft-candles)(being tested)
1.50	1	1.50	1	1.50	1	— Streetlight (2 ft-candles)(being tested)
4.00	4	4.00	4	4.00	4	— Bright room light (20 ft-candles)
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with a preference given to streetlight intensity (2 ft-candles) followed by full moonlight (0.01 ft candles).

Average Panel Ranking

Round 3		Round 2		Round 1		
Panel Rating	Panel Rank	Panel Rating	Panel Rank	Panel Rating	Panel Rank	11. **Of the following TIME options DURING WHICH THE LIGHTS ARE ON, which is most relevant to SECURITY.** **Please rank and explain under comments:**
1.00	1	1.00	1	1.25	1	— **100% (being tested)**
3.00	3	3.00	3	2.50	3	— **Random intermittent**
2.00	2	2.00	2	2.25	2	— **Directed spotlight as needed**
						— **Other (specify)**

CONCLUSION:

The ranking is consistent between rounds with a clear preference given to continual operation of the lights.

12. Of the following light SPECTRUM options, which is most helpful in improving SECURITY for LIGHTS SHINING ON THE PIER.

Please rank and explain under comments:

Average Panel Ranking

Round 3		Round 2		Round 1		
Panel Rating	Panel Rank	Panel Rating	Panel Rank	Panel Rating	Panel Rank	
1.25	1	1.25	1	1.25	1	— High pressure sodium (yellow white or gold) (being tested)
2.25	2	2.25	2	2.25	2	— Low pressure sodium (yellow)
2.75	3	2.75	3	3.00	3	— Mercury vapor (blue white)
4.75	5	4.25	5	4.50	4	— Halide (car headlight)
6.00	7	5.75	7	5.50	6	— Red
3.75	4	4.00	4	4.50	4	— Infrared with eye vision enhancement equipment on men
5.00	6	4.75	6	4.75	5	— Infrared with closed circuit TV
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with a clear preference to high pressure sodium followed by a closely ranked low pressure sodium and mercury vapor.

Average Panel Ranking

13. **Of the following light SPECTRUM options, which is most helpful in improving SECURITY for LIGHTS SHINING ON THE WATER.**

Please rank and explain under comments:

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	Option
1.33	1	1.33	1	1.67	1	— High pressure sodium (yellow white or gold) (being tested)
3.33	4	3.33	4	3.00	3	— Low pressure sodium (yellow)
2.00	2	2.00	2	2.67	2	— Mercury vapor (blue white)
2.67	3	3.00	3	3.33	4	— Halide (car headlight)
6.33	7	5.66	7	5.33	6	— Red
4.33	5	4.00	5	4.33	5	— Infrared with eye vision enhancement equipment on men
5.00	6	4.33	6	4.33	5	— Infrared with closed circuit TV
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with a clear preference given to high pressure sodium, followed by mercury vapor and a closely ranked halide.

14. For fog or other adverse weather conditions which SPECTRUM options might offer improved penetration of the light for pier or water surface SECURITY.

Please rank and explain under comments:

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	
2.00	2	2.50	2	2.50	2	— High pressure sodium (yellow white or gold)
1.00	1	1.25	1	2.25	1	— Low pressure sodium (yellow)
3.75	4	4.50	5	4.25	5	— Mercury vapor (blue white)
5.00	6	4.75	6	4.75	6	— Halide (car headlight)
5.50	7	6.00	7	6.00	7	— Red
3.50	3	3.50	3	3.50	3	— Infrared with eye vision enhancement equipment on men
4.25	5	4.25	4	3.75	4	— Infrared with closed circuit TV
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with a clear preference given to low pressure sodium followed by high pressure sodium.

15. **Of the following lighting FIXTURE HEIGHT options for an appropriate pole spacing, which is most helpful in improving SECURITY for LIGHTS SHINING ON THE PIER, without also compromising the guards vision by the lights shining in their eyes.**

Please rank and explain under comments:

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	Option
1.00	1	1.00	1	1.00	1	— 100 ft. (being tested)
2.00	2	2.25	2	2.25	2	— 75 ft.
3.75	4	3.50	4	3.25	3	— 50 ft. (being tested)
3.25	3	3.25	3	3.25	3	— Ankle height
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with a clear preference given to 100 ft followed by 75 ft.

16. **Of the following lighting FIXTURE HEIGHT options for an appropriate pole spacing, which is most helpful in improving SECURITY for LIGHTS SHINING ON THE WATER.**

Please rank and explain under comments:

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	Option
1.25	1	1.50	1	1.00	1	— **100 ft. (being tested)**
2.25	2	2.50	2	2.00	2	— **75 ft.**
3.75	4	3.75	4	3.00	3	— **50 ft. (being tested)**
4.50	5	4.00	5	3.75	4	— **Ankle Height (new option specified by one panel member)**
2.33	3	3.5	3	—	—	— **Under the water**
4.75	6	?	?	—	—	— **Under Pier** — **(new option specified by one panel member)**
						— **Other (specify)**

CONCLUSION:

The ranking is fairly consistent between rounds with a clear preference given to 100 feet, with a closely ranked second between 75 feet and under the water.

Average Panel Ranking						
Round 3		Round 2		Round 1		
Panel Rating	Panel Rank	Panel Rating	Panel Rank	Panel Rating	Panel Rank	17. **Of the following light POLE SPACING options for an appropriate fixture height, which is most helpful in improving SECURITY.** **Please rank and explain under comments:**
3.00	3	3.00	3	3.00	3	— **1260 ft.**
1.00	1	1.00	1	1.00	1	— **630 ft. (being tested)**
2.00	2	2.00	2	2.00	2	— **315 ft.**
						— **Other (specify)**

CONCLUSION:

The ranking is consistent between rounds with a clear preference given to 630 ft.

18. Of the following light REFLECTIVITY options on the pier surface, which is most helpful in improving SECURITY.

Please rank and explain under comments:

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	Option
1.50	2	1.50	1	1.50	1	— Gray (being tested)
3.50	4	3.50	3	3.75	3	— Black
2.25	3	2.50	2	2.50	2	— Yellow
1.25	1	1.50	1	1.50	1	— Intermittent beaded strips of retro-reflectors across pier (e.g. like highway lane dividers)
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with preference given to intermittent beaded strips followed closely by gray.

19. **Considering the light REFLECTIVITY on the water surface, which of the following SPECTRUM options most improves the ability of an observer to assess a SECURITY threat on the WATER SURFACE.**

Please rank and explain under comments:

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	Option
2.00	1	1.50	1	1.75	1	— High pressure sodium (yellow white or gold) (being tested)
2.50	2	2.50	2	2.50	2	— Low pressure sodium (yellow)
2.75	3	2.75	3	3.00	3	— Mercury vapor (blue white)
3.75	5	3.75	5	3.50	5	— Halide (car headlight)
3.00	4	3.00	4	3.25	4	— Infrared (with appropriate visual dispaly)
						— Other

CONCLUSION:

The ranking is consistent between rounds with preference given to high pressures sodium but with a close ranking of low pressure sodium and mercury vapor.

20. Of the following pier ACTIVITIES, which is most important to provide lighting for in order to improve pier SAFETY and OPERATIONS.

Please rank and explain under comments:

Average Panel Ranking

	Round 3		Round 2		Round 1	
Activity	Panel Rating	Panel Rank	Panel Rating	Panel Rank	Panel Rating	Panel Rank
— Brow placement	5.75	6	5.5	6	4.00	6
— Mooring/berthing	3.50	4	3.5	4	3.25	4
— Utility hookups	5.25	5	5.25	5	3.50	5
— Crane operations	2.00	2	2.00	2	2.50	2
— Cargo loading/unloading	3.00	3	3.00	3	2.75	3
— Vehicular transport	6.25	7	6.00	7	4.00	6
— Pedestrian traffic	1.50	1	1.50	1	2.25	1
— Other (specify)						

CONCLUSION:

The ranking is consistent between rounds with a clear preference given to pedestrian traffic followed by crane operations and cargo loading/unloading.

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	
						21. **Of the following lighted PIER AREA options, which would most benefit from improved lighting considering OPERATIONS and SAFETY issues.**
						Please rank and explain under comments:
1.00	1	1.00	1	1.00	1	— **Entire pier (being tested)**
2.00	2	2.00	2	1.75	2	— **Limited area of pier (specify under comments)**
3.75	4	3.50	4	3.25	4	— **Movable person size spot of light on pier**
3.25	3	3.25	3	3.00	3	— **Intermittent limited size spots along edge of pier (e.g., like runway lights)**
						— **Other (specify)**

CONCLUSION:

The ranking is consistent between rounds with a preference given to the length of the entire pier.

Average Panel Ranking

22. **Of the following lighting INTENSITY options, which is the minimum adequate for SAFE and EFFICIENT PIER OPERATIONS involving MOORING/BERTHING, BROW PLACEMENT, UTILITY HOOKUP, CRANE OPERATIONS, and CARGO LOADING.**

Please rank and explain under comments:

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	Option
4.00	4	4.00	4	3.75	4	— Starlight (0.001 ft-candles)
3.00	3	3.00	3	2.75	3	— Full moonlight (0.01 ft-candles) (being tested)
1.00	1	1.25	1	1.50	1	— Streetlight (2 ft-candles)(being tested)
2.00	2	1.75	2	2.00	2	— Bright room light (20 ft-candles)
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with a clear preference given to streetlight intensity (2 ft-candles).

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	Item
						23. **Of the following lighting INTENSITY options, which is the minimum adequate for SAFE and EFFICIENT PIER OPERATIONS involving VEHICULAR TRANSPORT and PEDESTRIAN TRAFFIC.**
						Please rank and explain under comments:
4.00	4	3.75	4	3.5	4	— **Starlight (0.001 ft-candles)**
2.75	3	3.25	3	2.5	3	— **Full moonlight (0.01 ft-candles) (being tested)**
1.00	1	1.00	1	1.25	1	— **Streetlight (2 ft-candles) (being tested)**
2.25	2	2.00	2	2.25	2	— **Bright room light (20 ft-candles)**
						— **Other (specify)**

CONCLUSION:

The ranking is consistent between rounds with a clear preference given to streetlight intensity (2 ft-candles).

24. What PERCENT (%) OF NIGHTTIME HOURS FOR A TYPICAL MONTH are lights likely to be used to improve the SAFETY and EFFICIENCY of PIER OPERATIONS involving MOORING/BERTHING.

Please rank and explain under comments:

Average Panel Ranking						
Round 3		Round 2		Round 1		
Panel Rating	Panel Rank	Panel Rating	Panel Rank	Panel Rating	Panel Rank	
1.50	1	1.75	2	2.00	2	— **Less than 5%**
1.50	1	1.25	1	1.75	1	— **5% to 10%**
3.00	2	2.25	3	2.25	3	— **10% to 15%**
4.00	3	4.00	4	3.50	4	— **Over 50%**
						— **Other (Specify)**

CONCLUSION:

The ranking is consistent between rounds with equal preference given to "Less than 5%" and "5% to 10%".

25. **What PERCENT (%) OF NIGHTTIME HOURS FOR A TYPICAL MONTH are lights likely to be used in order to improve the SAFETY and EFFICIENCY of PIER OPERATIONS involving UTILITY HOOKUP/BROW PLACEMENT.**

Please rank and explain under comments:

Average Panel Ranking

	Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank
— Less than 5%	1.50	1	1.75	2	2.00	2
— 5% to 10%	1.50	1	1.25	1	1.75	1
— 10% to 50%	3.00	2	3.00	3	2.25	3
— Over 50%	4.00	3	4.0	4	4.00	4
— Other (specify)						

CONCLUSION:

The ranking stabilized between with the 2nd and 3rd rounds with clear equal preference given to "less than 5%" and "5% to 10%".

26. What PERCENT (%) OF NIGHTTIME HOURS FOR A TYPICAL MONTH are lights likely to be used in order to improve the SAFETY and EFFICIENCY of PIER OPERATIONS involving CRANE OPERATIONS.

Please rank and explain under comments:

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	Option
1.00	1	1.25	1	1.25	1	— Less than 5%
2.00	2	2.00	2	1.75	2	— 5% to 10%
3.00	3	3.00	3	2.75	3	— 10% to 50%
4.00	4	3.75	4	3.75	4	— Over 50%
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with a clear preference given to "Less than 5%".

27. **What PERCENT (%) OF NIGHTTIME HOURS FOR A TYPICAL MONTH are lights likely to be used in order to improve the SAFETY and EFFICIENCY of PIER OPERATIONS involving CARGO LOADING/UNLOADING.**

Please rank and explain under comments:

Average Panel Ranking

	Round 3		Round 2		Round 1	
	Panel Rating	Panel Rank	Panel Rating	Panel Rank	Panel Rating	Panel Rank
— Less than 5%	1.00	1	1.00	1	1.25	1
— 5% to 10%	2.00	2	2.00	2	1.75	2
— 10% to 50%	3.00	3	3.00	3	2.75	3
— Over 50%	4.00	4	4.00	4	3.75	4
— Other (specify)						

CONCLUSION:

The ranking is consistent between rounds with a clear preference given to "Less and 5%".

28. What PERCENT (%) OF NIGHTTIME HOURS FOR A TYPICAL MONTH are lights likely to be used in order to improve SAFETY and EFFICIENCY of PIER OPERATIONS involving VEHICULAR TRANSPORT and PEDESTRIAN TRAFFIC.

Please rank and explain under comments:

Average Panel Ranking

	Round 3		Round 2		Round 1	
	Panel Rating	Panel Rank	Panel Rating	Panel Rank	Panel Rating	Panel Rank
— Less than 5%	3.75	4	3.75	4	3.25	3
— 5% to 10%	2.25	2	2.25	2	2.50	2
— 10% to 50%	1.00	1	1.00	1	1.75	1
— Over 50%	2.50	3	2.50	3	2.50	2
— Other (specify)						

CONCLUSION:

The ranking is consistent between rounds with a clear preference given to "10% to 50%".

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	29. Of the following light SPECTRUM options FOR LIGHTS SHINING ON THE PIER, which is most helpful to improve the SAFETY and EFFICIENCY of PIER OPERATIONS involving activities such as MOORING/BERTHING, UTILITY HOOKUPS, BROW PLACEMENT and OTHER DAY TO DAY OPERATIONS. Please rank and explain under comments:
1.25	1	1.25	1	1.25	1	— High pressure sodium (yellow white or gold) (being tested)
1.75	2	1.75	2	2.50	2	— Low pressure sodium (yellow)
3.00	3	2.75	3	3.00	3	— Mercury vapor (blue white)
4.25	4	4.00	4	3.75	4	— Halide (car headlight)
4.75	5	4.50	5	4.50	5	— Red
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with preference given to high pressure sodium followed closely by low pressure sodium.

30. **For fog or other adverse weather conditions which SPECTRUM options might offer improved penetration of the light for pier or water surface SAFETY and OPERATIONS.**

Please rank and explain under comments:

Average Panel Ranking

	Round 3		Round 2		Round 1	
	Panel Rating	Panel Rank	Panel Rating	Panel Rank	Panel Rating	Panel Rank
— High pressure sodium (yellow white or gold)	1.25	1	1.25	1	1.25	1
— Low pressure sodium (yellow)	1.50	2	1.50	2	1.50	2
— Mercury vapor (blue white)	3.00	3	3.00	3	3.25	3
— Halide (car headlight)	4.00	4	4.00	4	3.50	4
— Red	4.25	5	4.25	5	4.00	5
— Other (specify)						

CONCLUSION:

The ranking is consistent between rounds with preference given to high pressure sodium followed by a closely ranked low pressure sodium.

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	
						31. **Of the following light FIXTURE HEIGHT options, which is most helpful to achieve SAFE and EFFICIENT PIER OPERATIONS involving MOORING/BERTHING, UTILITY HOOKUP, BROW PLACEMENT, CRANE OPERATIONS, and CARGO LOADING AND UNLOADING.** **Please rank and explain under comments:**
1.00	1	1.00	1	1.00	1	— **100 ft. (being tested)**
2.00	2	2.00	2	2.00	2	— **75 ft.**
3.25	3	3.25	3	3.25	3	— **50 ft. (being tested)**
3.75	4	3.75	4	3.75	4	— **Ankle Height**
						— **Other (specify)**

CONCLUSION:

The ranking is consistent between rounds with preference given to 100 ft followed by 75 ft.

32. Of the following lighting FIXTURE HEIGHT options, which is most helpful to achieve SAFE and EFFICIENT PIER OPERATIONS involving VEHICULAR TRANSPORT and PEDESTRIAN TRAFFIC.

Please rank and explain under comments:

- **100 ft. (being tested)**
- **75 ft.**
- **50 ft. (being tested)**
- **Ankle Height**
- **Other (specify)**

Average Panel Ranking

Round 3		Round 2		Round 1	
Panel Rating	Panel Rank	Panel Rating	Panel Rank	Panel Rating	Panel Rank
1.00	1	1.00	1	1.00	1
2.00	2	2.00	2	2.00	2
3.25	3	3.25	3	3.25	3
3.75	4	3.75	4	3.75	4

CONCLUSION:

The ranking is consistent between rounds with preference given to 100 ft followed by 75 ft.

33. **Of the following light POLE SPACING options, for an appropriate fixture height, which is most helpful to achieve SAFE and EFFICIENT PIER OPERATIONS involving MOORING/BERTHING, BROW PLACEMENT/UTILITY HOOKUP, CRANE OPERATIONS, and CARGO LOADING AND UNLOADING.**

Please rank and explain under comments:

Average Panel Ranking

	Round 3		Round 2		Round 1	
Option	Panel Rating	Panel Rank	Panel Rating	Panel Rank	Panel Rating	Panel Rank
— 1260 ft.	2.75	3	2.75	3	2.5	3
— 630 ft. (being tested)	1.00	1	1.00	1	1.5	1
— 315 ft.	2.25	2	2.25	2	2.0	2
— Other (specify)						

CONCLUSION:

The ranking is consistent between rounds with preference given to 630 ft.

Average Panel Ranking						
Round 3		Round 2		Round 1		
Panel Rating	Panel Rank	Panel Rating	Panel Rank	Panel Rating	Panel Rank	**34. Of the following light POLE SPACING options, for an appropriate fixture height, which is most helpful to achieve SAFE and EFFICIENT PIER OPERATIONS involving VEHICULAR TRANSPORT, and PEDESTRIAN TRAFFIC.** **Please rank and explain under comments:**
2.25	2	2.25	2	2.5	2	**— 1260 ft.**
1.50	1	1.50	1	1.0	1	**— 630 ft. (being tested)**
2.25	2	2.25	2	2.5	2	**— 315 ft.**
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with preference given to 630 ft.

35. Considering the following light REFLECTIVITY options on the pier surface, which is most helpful in achieving SAFE and EFFICIENT PIER OPERATIONS.

Please rank and explain under comments:

Average Panel Ranking

Round 3 Panel Rating	Round 3 Panel Rank	Round 2 Panel Rating	Round 2 Panel Rank	Round 1 Panel Rating	Round 1 Panel Rank	Option
1.00	1	1.00	1	1.25	1	— Gray (being tested)
3.00	3	3.00	3	3.00	3	— Black
2.00	2	2.00	2	1.75	2	— Yellow
						— Other (specify)

CONCLUSION:

The ranking is consistent between rounds with preference given to gray.

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PWC Code 1011, Pearl Harbor, HI; Code 123-C, San Diego, CA; Code 400, Oakland, CA; Code 412, San Diego, CA; Code 423/KJF, Norfolk, VA; Code 50, Pensacola, FL; Code 612, Pearl Harbor, HI
SUBASE Bangor, PWO (Code 8323), Bremerton, WA; SCE, Pearl Harbor, HI

DEPARTMENT OF THE NAVY

Naval Civil Engineering Laboratory
Port Hueneme, CA 93043-5003

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☐ FORM ☒ PUBLICATION ☐ TECH MANUAL ☐ MICROPUBLISHING ☐ OTHER **FY 90**

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27	4-0	PI-00027	72	

FILL OUT FORM IN DUPLICATE

CUSTOMER JOB NO.	NPPSO JOB NO.
	10782

DATE REQUESTED	DATE REQUIRED
1/3/90	1/26/90

(CLASSIFICATION (check one)

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33	120

PAPER	(Size)	(Kind)	(Color)
COVER	8 1/2 X 11	65# cover	Gold
TEXT	8 1/2 X 11	60# offset	white

DESCRIPTION (Pub title, form no, etc.)

Pier Lighting Requirements

Test Program - R 81,017

IF FORM CHECK APPROPRIATE BOX

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☐ ONE UP LEFT ☒ TWO SIDE ☐ SADDLE ☐ SEE REMARKS

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FOR 40 PAGE PUBLICATIONS OR LESS FILL IN THE COLLATION LIST – ING AT RIGHT →

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	FRONT	BACK		FRONT	BACK
1			11		
2			12		
3			13		
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7			17		
8			18		
9			19		
10			20		

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AUTHORIZED BY	PERIOD OF TIME

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REQUESTOR: L.D. Triem

ACTIVITY	CODE	EXT.	BLDG.
NCEL	L34	1689	

JOB RECEIVED BY	DATE

SCHEDULE DATE & INITIAL	TIME UNITS	PROD STD		PROCESS TITLE/NO.		ACTUAL PRODUCTION UNITS	MSRE UNIT	PRICE	BILLING AMOUNT
		.0185	C	COPY PREP	100		MIN	.62	
		.0250	NEG	NEGATIVE	200		8½ x11	1.30	
		.0344	NEG	STRIP/REFLAT	202		8½ x11	1.41	
		.0153	NEG	DEFLAT	203		UNIT	.49	
		.0144	M	PLATE	210		UNIT	1.10	
		.0588	JOB PRINTING	MAKE-READY	300		MR	1.70	
		.0002	JOB PRINTING	RUN 10x15	301		IMP	.0102	
		.0002	JOB PRINTING	RUN (11x17)	302		IMP	.0102	
		.0002	SYS DUP	RUN 1 THRU 50	320		IMP	.0155	
		.0001	SYS DUP	RUN OVER 50	321		IMP	.0115	
		.2000	17x22	M/R	330		MR	6.75	
		.0002	17x22	RUN	331		IMP	.0125	
			P	PAPER	390		COST +		110
		.0666	FOLD	M/R	400		MR	3.25	
		.0002	FOLD	RUN	401		RUN	.0115	
		.0500	COLL	M/R COLLATE	410		MR	1.34	
		.0001	COLL	RUN COLLATE	411		RUN	.0062	
		.0005	COLL	HAND ASSEMBLY	412		HP	.02	
		.0024	P/D	PUNCH/DRILL	420		UNIT	.1023	
		.0002	P/D	P.COMB/BIND	421		SHEET	.0122	
		.0013	STITCH & STPL	SIDE STITCH	430	240	IMPACT	.041	
		.0020	STITCH & STPL	SADDLE	431		IMPACT	.084	
		.0020	MISC BINDERY	PAD	440		PAD	.0715	
		.0166	MISC BINDERY	ACCO FASTEN	441		FAS'NR	.57	
		.0125	MISC BINDERY	SCREW POST	442		POST	.47	
		.0033	MISC BINDERY	GLUE BIND	443		UNIT	.1023	
		.0019	W	WRAP/PACK	450	140	UNIT	.0715	
		.0111	W	SHRINK WRAP	451	120	UNIT	.3887	
		.0185	SUNDRY LABOR	MISC BINDERY	470		MIN	.56	
		.0185	SUNDRY LABOR	PREP FOR MAIL	471		MIN	.56	
		.0185	SUNDRY LABOR	DISTRIBUTION TO MULTI ADDRESSES	472	240	MIN	.56	
		.0185	SUNDRY LABOR	CLASSIFIED MATERIAL	473		MIN	.56	
		.0021	COPY	DUPE ORIGINAL	500		COPY	.12	
		.0002	COPY	RUN (1-50)	501		IMP	.0175	
55		.0002	COPY	RUN (OVER 50)	502	29,040	IMP	.0155	
		.0010	COPY	ADJACENT STITCHING	503		IMP	.0102	
		.0142	COPY	COLOR COPIERS	532		COPY	1.12	
		.0015	SC	OCE 7500	534		RUN FT	.15	
		.0185	SC	LABOR	535		MIN	.56	
			CONTRACT	NAVY	600		COST + 5.5%		
			CONTRACT	GPO/RPO	601		COST + 5.5%		
			CONTRACT	FED'L PRISON	603		COST + 5.5%		
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FOR REFERENCE CONSULT	PHONE
P. D. Triem (D. Bush)	X-1689

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17X4912.2560	000	77777	0	068305	2F	000000	000T07500128		$1,000.00

FORM/PUBLICATION NO. AND TITLE (In that order)

CR 89.017, "Pier Lighting Requirements Test Program - Final Report" (Milmont)

QTY. (Specify shts, sets, etc.)	PAGES	QTY. WILL LAST	JOB TO BE REPRINTED	JOB IS	LAST JOB NO.
120	233	MOS.	☐ YES ☒ NO	☒ NEW ☐ REVISED ☐ A REPRINT	

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6.		
7.		

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COLLATION AND DATA RECORD
PAGE SEQUENCE AND FOLDOUT INSTRUCTIONS FOR PRINTER
GEN-5603/1 (REV. 5-86) S/N 0190-LF-054-3004

CR 89.017

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PLANT JOB NO.

SHEET 1 OF 2

List blank pages by a slant mark (/); see NPPS WESTDIVINST 5600.1, for instructions on marking foldouts, back cover, etc.

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Otherwise (for self-cover), start on "Sheet No. 1" line.
RECOMMENDED FOLDOUT LENGTHS ARE 17½", 22½", 35", AND 45"

SHT. NO.	FRONT	BACK	FOLDOUTS DESIRED IMAGE SIZE	FOLDOUTS DESIRED SHEET SIZE
	Cover	Cover Chart		
1	SF298	Blank		
2	iii	iv		
3	V	VI		
4	VII	VIII		
5	IX	X		
6	XI	XII		
7	XIII	XIV		
8	XV	XVI		
9	XVII	XVIII		
10	1-1	1-2		
11	1-3	1-4		
12	1-5	1-6		
13	1-7	1-8		
14	1-9	1-10		
15	1-11	Blank		
16	2-1	2-2		
17	2-3	2-4		
18	2-5	2-6		
19	2-7	2-8		
20	2-9	2-10		
21	2-11	2-12		
22	2-13	2-14		
23	2-15	2-16		
24	2-17	2-18		
25	2-19	2-20		
26	2-21	2-22		
27	2-23	2-24		
28	2-25	2-26		
29	2-27	2-28		
30	2-29	2-30		
31	2-31	2-32		
32	2-33	2-34		

SHT. NO.	FRONT	BACK	FOLDOUTS DESIRED IMAGE SIZE	FOLDOUTS DESIRED SHEET SIZE
33	2-35	2-36		
34	2-37	2-38		
35	2-39	2-40		
36	2-41	2-42		
37	2-43	2-44		
38	2-45	2-46		
39	2-47	2-48		
40	2-49	2-50		
41	2-51	2-52		
42	3-1	3-2		
43	3-3	3-4		
44	3-5	3-6		
45	3-7	3-8		
46	3-9	3-10		
47	3-11	3-12		
48	3-13	3-14		
49	3-15	3-16		
50	3-17	3-18		
51	3-19	3-20		
52	3-21	3-22		
53	3-23	3-24		
54	3-25	3-26		
55	3-27	3-28		
56	3-29	3-30		
57	3-31	Blank		
58	4-1	4-2		
59	4-3	4-4		
60	4-5	4-6		
61	4-7	4-8		
62	4-9	4-10		
63	4-11	4-12		
64	4-13	4-14		

SHT. NO.	FRONT	BACK	FOLDOUTS DESIRED IMAGE SIZE	FOLDOUTS DESIRED SHEET SIZE
65	4-15	4-16		
66	4-17	4-18		
67	4-19	4-20		
68	4-21	4-22		
69	4-23	4-24		
70	4-25	4-26		
71	4-27	4-28		
72	4-29	4-30		
73	4-31	4-32		
74	4-33	4-34		
75	4-35	4-36		
76	4-37	4-38		
77	4-39	4-40		
78	4-41	4-42		
79	4-43	4-44		
80	4-45	4-46		
81	4-47	4-48		
82	4-49	4-50		
83	4-51	4-52		
84	4-53	Blank		
85	5-1	5-2		
86	5-3	5-4		
87	5-5	5-6		
88	5-7	5-8		
89	5-9	5-10		
90	5-11	5-12		
91	5-13	5-14		
92	5-15	5-16		
93	5-17	Blank		
94	6-1	6-2		
95	6-3	6-4		
96	6-5	6-6		
97	6-7	6-8		
98	6-9	6-10		
99	6-11	6-12		
100	7-1	Blank		

REMARKS

NCEL/L34

COLLATION AND DATA RECORD
PAGE SEQUENCE AND FOLDOUT INSTRUCTIONS FOR PRINTER
GEN-5603/1 (REV. 5-86) S/N 0190-LF-054-3004 CR 89.017

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PLANT JOB NO.

SHEET 2 OF 2

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SHT. NO.	FRONT	BACK	FOLDOUTS		SHT. NO.	FRONT	BACK	FOLDOUTS		SHT. NO.	FRONT	BACK	FOLDOUTS	
			DESIRED IMAGE SIZE	DESIRED SHEET SIZE				DESIRED IMAGE SIZE	DESIRED SHEET SIZE				DESIRED IMAGE SIZE	DESIRED SHEET SIZE
1	A-1	A-2	7-2		33					65				
2	A-3	A-4			34					66				
3	A-5	A-6			35					67				
4	A-7	A-8			36					68				
5	A-9	A-10			37					69				
6	A-11	A-12			38					70				
7	A-13	A-14			39					71				
8	A-15	A-16			40					72				
9	A-17	A-18			41					73				
10	A-19	A-20			42					74				
11	A-21	A-22			43					75				
12	A-23	A-24			44					76				
13	A-25	A-26			45					77				
14	A-27	A-28			46					78				
15	A-29	A-30			47					79				
16	A-31	A-32			48					80				
17	A-33	A-34			49					81				
18	A-35	A-36			50					82				
19	Dist List	/			51					83				
Back	Cover	/			52					84				
21					53					85				
22					54					86				
23					55					87				
24					56					88				
25					57					89				
26					58					90				
27					59					91				
28					60					92				
29					61					93				
30					62					94				
31					63					95				
32					64					96				
										97				
										98				
										99				
										100				

REMARKS