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in candidacy for the degree of

Master of Fine Arts

CUPH:
A SYNERGISTIC AQUATIC CAMERA DESIGN

by

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And special thanks to my mother and father, Ruth and Richard Smokowski, for having the faith to allow me this opportunity to learn and the patience and means to allow me to succeed.

This thesis is dedicated to

Ms. Mary Ann SanFilippo,

without who's love and inspiration I never could have started.

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INTRODUCTION

The undersea world is awe inspiring. Underneath the waves there exists an alien territory that is filled with creatures, treasures, and wonders that are as strange to us as our wildest fantasy; they nearly surpass the imagination. Few people are able to plunge into this world without being captivated by the experience.

Being surrounded by a mysterious, strange new world is a completely unnatural experience and a very personal one, since it is quite literally a life-threatening situation. Having dived and survived initiates you into the ranks of adventurers and explorers who have shared the vision of this domain. Every diver feels compelled to share the story of what they have discovered under the waves.

Underwater photography is by far the most effective way to share these stories. However, underwater photography is an extremely difficult task; it requires the operation of complex, delicate, and demanding equipment in an unfamiliar and sometimes hostile environment. Although a versatile underwater camera in the hands of a skilled underwater photographer can capture spectacular images, for most diving enthusiasts, whose desires for quality results are just as strong as the professional's, underwater photography presents a number of formidable challenges in a uniquely stressful situation.

Motivation

The unique difficulties associated with underwater photography first came to my attention several years ago, while I was working in a local camera store. This store carried a full range of camera styles and models from all the major manufacturers. From disposable cameras to single lens reflexes, autofocus point-and-shoots to professional-quality equipment, all were present. However, there were very few cameras in the store that were capable of taking pictures underwater, compared to the number of other models we carried. Only two or three at most were available. These were significantly more expensive than most other cameras and offered fewer modes and features than all but the simplest regular models.

Occasionally, people would come into the store and scrutinize the cameras in our display cases with a burning curiosity and focused intensity that distinguished their motives from our other customers. They were obviously looking for something special. After intently investigating every shelf, they would approach a sales person and ask "*what kind of camera do I need to take pictures underwater?*" An explanation that they were avid divers who wanted some way to show other people what they had experienced underwater, inevitably followed.

Some of these customers were not experienced photographers and thought that the basic automatic underwater cameras we carried would fit their needs perfectly. They wanted something capable of capturing underwater images without being too difficult to operate. Others wanted to investigate the full range of equipment available, before making any decisions. The only way that we could help those who wanted more information was to suggest local scuba shops that might carry a wider range of equipment, or could order more sophisticated models.

Most of the diving enthusiasts that bought cameras from us would come back later with numerous rolls of film from their excursions, ask for the quickest possible service available, order multiple sets of prints, and leave in great anticipation. On more than one occasion, the customer patiently waited on a bench outside the store for their photos to be finished.

Picking up their processing, they were almost always disappointed with the results. Even though the pictures they had taken on land looked fine, from the same roll of film, the prints of the underwater scenes appeared mostly vague and fuzzy, pale and blue. The underwater photos were not at all what they had expected, or what they had seen in reality. Confused, in hope of determining what went wrong, the divers would usually mention that although it worked well for the shots around the beach, in the water, the camera became very difficult to use. Bewildered and frustrated, they would pack up their pictures, shrug and walk away.

It was disconcerting to see people that were truly enthusiastic end up so disappointed. Whether the poor quality of the photographic results diminished their interest in diving is difficult to say. However, the results certainly did not enhance the experience, as intended.

The frustration of these disheartened enthusiasts made me wonder what exactly was the cause of these problems. Was it their inexperience with the new equipment? Was there something wrong with the camera, or the film? Did they just happen to dive on a day when the water was extra murky? Was the film ruined by airport-security x-ray machines? The stream of questions flowed steadily, and multiplied each time this scene was repeated.

Why were there so few cameras readily available for diving enthusiasts? One would be led to believe that the unique problems associated with underwater photography must be particularly formidable. If not, then all the camera companies would be producing models for underwater use. Why were the available underwater cameras so much less automated and sophisticated than the regular ones?

Thinking about these questions convinced me that it would be a truly worthy challenge to design an underwater camera to minimize these problems. There was an apparent need and a strong desire for this kind of equipment (at the very least by casual diving enthusiasts) and a tremendous amount of unfulfilled potential that recent technology presented, just waiting to be applied. Without question, this was worth exploring in depth.

This thesis is an attempt to find a simplified solution to the problems of underwater photography by creating an alternate camera format for underwater use. This format will precisely respond to the context and unique challenges of recording an image in an aqueous environment.

EXAMINATION

Must underwater photography be such a frustrating experience? This question is surprisingly convoluted. To answer it requires exploring the primary factors that produce these frustrations.

Many factors are involved in creating the frustration that divers feel towards their cameras. These factors include but are not limited to: who is using the equipment, how much experience that person has as a diver and a photographer, what kind of camera is being used, what does the diver expect from the camera, and whether or not this is a reasonable expectation. Other factors include how the equipment is intended to be used, if it can in fact be used in this manner, and what kind of results the camera gives under different conditions.

The first set of questions lead in directions that are much too expansive for this paper and would result in redesigning the diver by changing what they think, do, or know. Since we intend to alter the artifact and not the user, the demands made by the camera on the diver and the results the camera gives in return are the factors that are most important to this paper. The difficulties encountered by the diver when using existing underwater photographic equipment and the characteristics of the equipment that tend to produce poor quality results are the issues that must be examined both to understand the present situation and to change it.

The degree of difficulty experienced when using existing photographic equipment underwater is hard to imagine while on dry land. Standing on a floor, trying out a new camera, the factors that are encountered once you plunge beneath the waves can not be fully anticipated.

How can the difficulty of using underwater photographic equipment be evaluated? Trying to examine this equipment poses a substantial challenge. Every camera model has unique quirks of operation that may create difficulties when used underwater. Cataloging these would say little about fundamental problems. It is the difficulties present in *all* varieties of existing underwater photographic equipment that are most important. Such problems result from similarities that all these cameras possess. The primary feature that all existing underwater photographic equipment share is the 35 mm camera format. *These common problems are caused by the way the camera's **format** interacts with the aquatic environment.* For this reason, the camera's format must be the initial focus of our examination.

The other main cause of the frustration divers feel towards their photographic equipment is the image quality of results obtained. For optimum photographic results the camera's mechanisms must be properly set to accommodate the quantity and state of the incoming light. Barring deficiencies in the film or camera, and mishandling while being processed, poor image quality occurs when the light forming the image is either in the wrong state (not properly focused on the film) or is of the wrong quantity (either under or over exposed) to record a well-defined image of the desired subject. Poor results exclusively on underwater photographs indicates that although capable of responding well to the situations encountered on land, *the camera's systems are prevented from responding properly to the light by the underwater environment.*

It is important to recognize that the difficulty operating a camera and the quality of the resulting images are not *necessarily* correlated; a camera that is difficult to use does not automatically give poor results. Beautiful photographs have been obtained with the most difficult and finicky equipment and cameras that are easy to use too often give poor results. To assume that difficulty in operation causes poor results would be a mistake without first evaluating the relationship between the two symptoms and their causes. Such reasoning would lead to increasingly 'simplified' equipment, that continually fails to remedy the problems. To eliminate frustrations, photographic equipment does *not* need to be *simple*, it needs to be *appropriate*.

Is the existing equipment appropriate for taking pictures underwater? In order to properly answer this question the equipment's format must first be examined. With this information in mind, both the difficulties caused by camera format and the quality of the photographic results can be evaluated. Scrutinizing these problems and their causes leads to the conviction that the frustrations experienced with existing underwater photographic equipment can be avoided.

Format

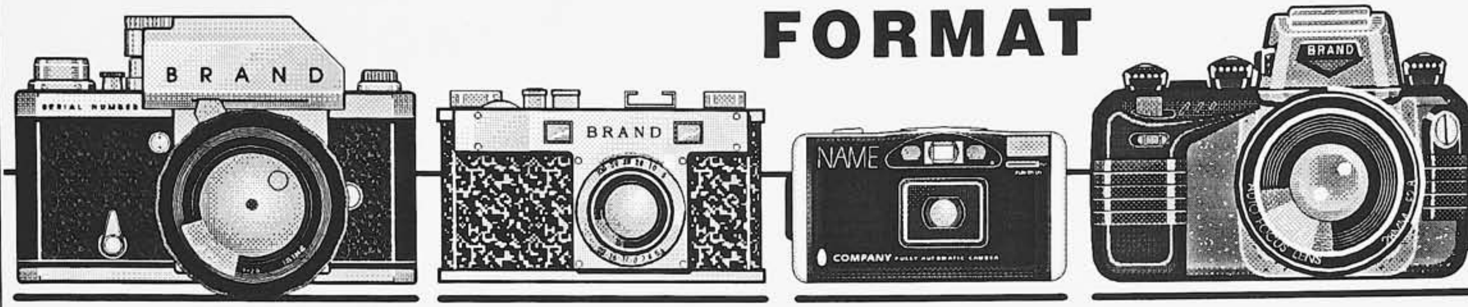
Camera format typically refers to the size of film a camera takes. In this report, the term is used in a broader sense. Here **format** refers to the size and dimensions of a camera, the arrangement of its primary components, and its method of operation.

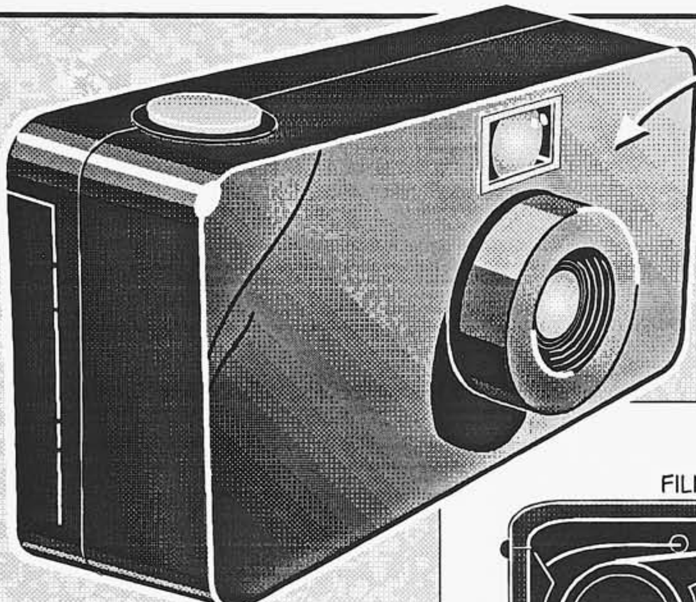
To fully understand the difficulties of operating photographic equipment underwater that are caused by the camera's *format*, and why these problems occur, both the physical characteristics of the format and the tasks that it requires of the photographer must be understood.

Because every camera has definite limitations, a wide range of camera models have been developed to accommodate the needs of a variety of users and uses. Even though there are a vast array of differences, all 35 mm cameras share a common format since all share the same basic configuration and are operated the same way.

The standard 35 mm camera format consists of a horizontal, oblong box that is wide, tall, and shallow (Figure 2.0). It has a lens mounted towards the middle of its front face and a viewing device that is mounted at the top of the camera, roughly above the lens. In this format, the camera is held by the photographer's right hand, which grips it along the right side. The photographer must direct and steadily support the camera for the duration of the exposure. With one eye closed, the viewfinder is held up to the other eye for previewing and composing the picture. The image is captured by triggering a shutter button with the right index finger. *The format provides the interface between the photographer and the camera's mechanisms.*

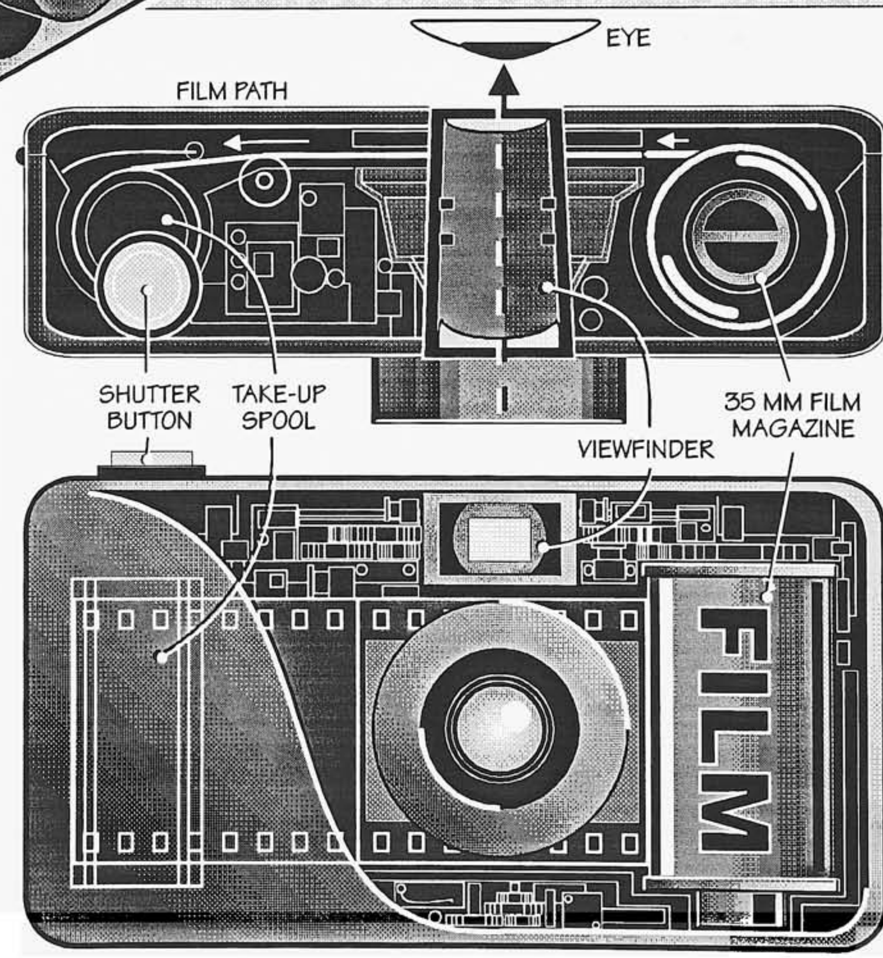
REGARDLESS OF THEIR DIFFERENCES, ALL 35 MM CAMERAS SHARE A COMMON FORMAT





A CAMERA'S FORMAT CAN BE SEEN IN THE CONFIGURATION OF ITS COMPONENTS.

ALL 35 MM FORMAT CAMERAS ARE OBLONG BLACK BOXES THAT ARE GRIPPED ALONG THE RIGHT SIDE. THEY HAVE SHUTTER BUTTONS ON THE RIGHT SIDE OF THEIR TOP FACE AND HAVE WINDOWS FOR PREVIEWING THE IMAGE (VIEWFINDERS) ON THEIR BACKS.



THE 35 MM FORMAT HAS BEEN DESIGNED TO BE COMPACT, VERSATILE, AND CONVENIENT.

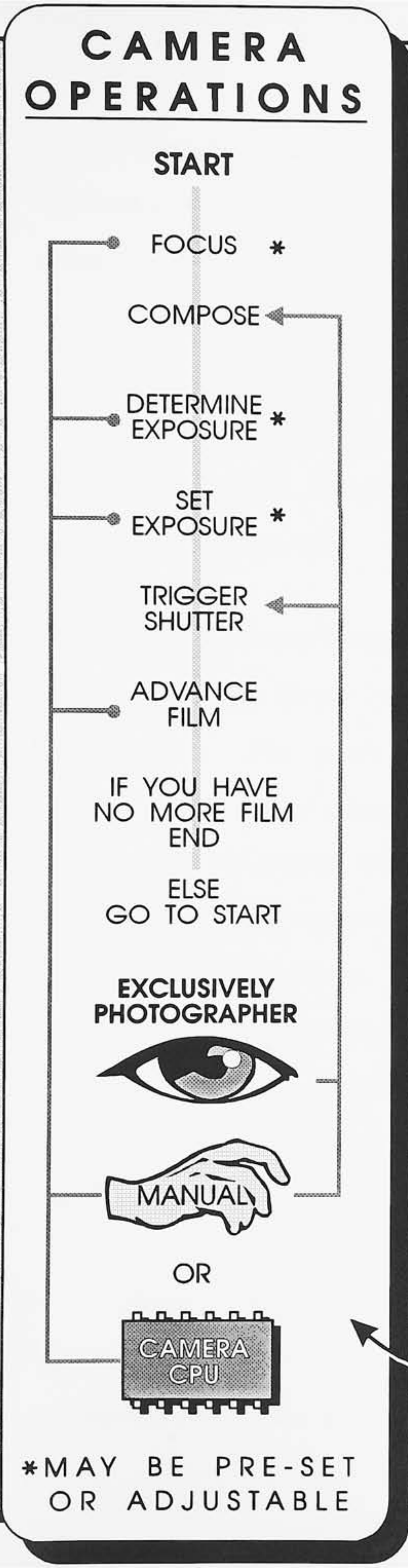
EVIDENCE OF THIS IS THE FORMAT'S "SMALL" SIZE; IT IS INTENTIONALLY EASY TO HOLD, MANIPULATE, AND TRANSPORT.

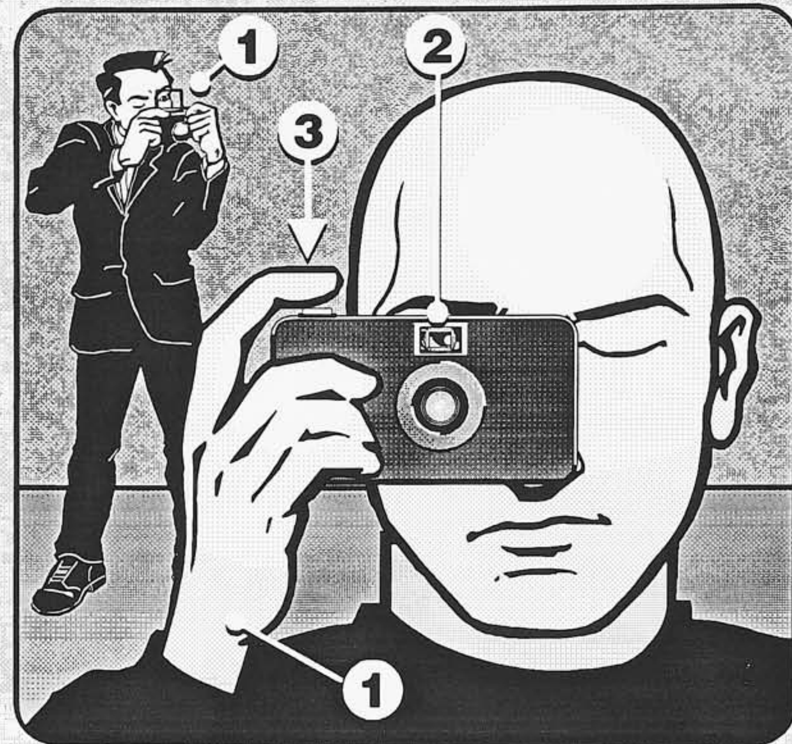
ITS SIMPLIFIED CONTROLS ACCOMMODATE A LARGE NUMBER OF USERS WITH VARYING SKILLS.

ITS VIEWFINDERS PREVIEW ACCURATELY AND KEEP THE UNIT'S SIZE DOWN.

THE FORMAT ACTS AS AN INTERFACE BETWEEN THE PHOTOGRAPHER AND THE CAMERA'S MECHANISMS.

FIGURE 2.0





BASIC TASKS REQUIRED OF THE PHOTOGRAPHER

1. **SUPPORT- STEADILY HOLD THE CAMERA IN PLACE FOR THE DURATION OF THE EXPOSURE.**
2. **COMPOSE- USING VIEWFINDER, DIRECT THE CAMERA AT THE DESIRED SUBJECT/BACKGROUND.**
3. **CONTROL- TRIGGER THE SHUTTER AT THE PROPER MOMENT.**

THESE TASKS ARE DEFINED BY THE CAMERA'S FORMAT.

THE SPECIFIC CONDITIONS OF WHO IS USING THE CAMERA, WHERE THEY ARE, AND HOW IT IS TO BE USED ALL DETERMINE HOW DIFFICULT IT IS TO OPERATE.

QUALITY OF RESULTS ARE DETERMINED BY PROPER FOCUS, EXPOSURE, AND COMPOSITION. DIFFICULTY IN SUPPORTING, COMPOSING, OR CONTROLLING CAN SEVERELY DEGRADE RESULTS.

FIGURE 2.1

Although there are substantial variations in the size and the operation of different camera models, the same basic tasks required by the format—supporting, composing, and controlling—must be performed in every case. On most cameras, these tasks can be achieved through a primary method of operation as well as various back-up methods. For example, a camera can be hand held or it may be mounted on a tripod. This illustrates operational flexibility and does not change the fact that the camera's size, shape, and placement of controls all indicate that it was *primarily* intended to be hand-held.

Judging from its compact size, vast array of features, and ever increasing level of automation, the 35 mm camera format has been developed to be both convenient and versatile. This would allow the largest possible range of users to take photographs of diverse subjects under varying conditions with minimal difficulty. To achieve such performance, the camera's components are tightly packed into a housing that can be steadily held and readily manipulated. This ensures that the camera is easy to support and control. Viewfinders are designed to be as small as possible and are strategically located to keep the overall size to a minimum. Cameras using the 35 mm format can capture portraits, snapshots, sports highlights, photos of mountains or insects with equal ease and yield agreeable results. The format seems so versatile that one may easily assume that it is ideally suited to every conceivable purpose.

Unfortunately, this is not the case. Just as individual cameras have specific limitations, the 35 mm format also has distinct limitations. These limitations are encountered when the photographer is forced to utilize the equipment in a way it was not intended to be used. This becomes unavoidable when the photographers' physical capabilities or the environmental constraints placed upon them *necessitate* using the equipment in ways that conflict with how the format was designed to operate.

For example: left handed photographers and people who are missing or have a severely impaired right arm may encounter great difficulty supporting, directing, or operating normal "right handed" cameras. People who wear glasses or people with large noses are prevented from positioning the camera close enough to their eyes to properly see through the viewfinder. Consequently, they have difficulty reading the control panel, and cannot properly compose or determine what will be in the picture using the viewfinder.

The format's limitations cause difficulty whenever such unanticipated situations arise. These constraints may be ingeniously compensated for, but are never entirely overcome. The result is always more complicated and cumbersome operation for the user. Underwater photography poses similar problems.

Existing Equipment

There are two major varieties of existing underwater photographic equipment. Both use the conventional 35 mm camera format and are primarily concerned with protecting the camera's delicate interior components from the irreparable damage caused by immersion in water.

An unprotected camera can not function underwater. The destructive effects of water poses a real threat to lenses, mechanisms and circuitry. Short circuits, corrosion of metal parts, increased wear, and fungal growth between the lenses are just some of the kinds of damage that can be caused by immersion. Liquids are so harmful because they can easily maneuver the various twists and turns inside the camera's body that have been designed to keep out stray light. To further complicate matters, after entering the body, water has a very difficult time leaving it. The same labyrinth that keeps out light catches evaporating vapor and traps the debris carried in by the water. Water damage to a camera is almost impossible to repair, so it is best to avoid it entirely.

Protecting the camera's functional elements from water damage is both the initial challenge and most obvious obstacle to creating a camera that will function underwater. Only a fully waterproof physical barrier can prevent liquids from penetrating the camera's body and damaging its components. Both varieties of existing underwater photographic equipment use barriers to protect these delicate mechanisms when submerged.

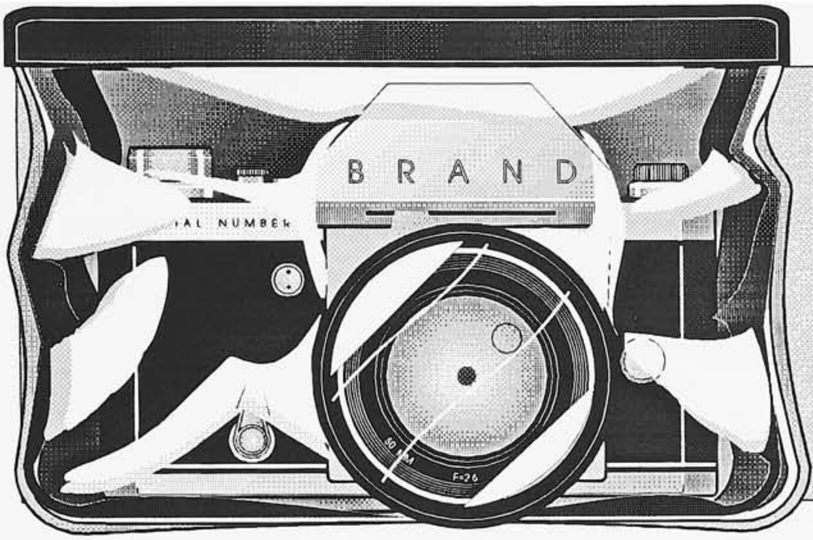
Housings

The first category of underwater photographic equipment is composed of ordinary cameras encased in waterproof housings (Figure 2.2). Such housings create an external physical barrier that prevents water from reaching the camera when submerged. This allows the camera to operate in an environment that would otherwise destroy it. The camera-plus-housing system retains the standard land format since it is still supported, operated and directed exactly as it would be on land. The camera is the dominant functional component of the system. Besides its protective role, the housing does not serve any constructive photographic purpose. The camera's capabilities have been artificially extended by the addition of a passive, defensive element.

Divers who were determined to take photographs underwater were the first to develop housings. They used simple tools in basement workshops and garages to construct protective shells from available materials that would let light in and kept water out. These home-made housings enabled the divers to successfully take pictures underwater with cameras that they already had.

Housings can assume a wide variety of shapes and forms and can be rigid or flexible, partially opaque or wholly transparent, metal, wooden, plastic or glass, or nearly any combination of materials. They can still be improvised in a shop, but are now also mass produced in moderate quantities. Mass produced housings range from the fairly crude devices (zip-lock bags) to the highly sophisticated models (form-fitting injection-molded composite-material ergonomic shells).

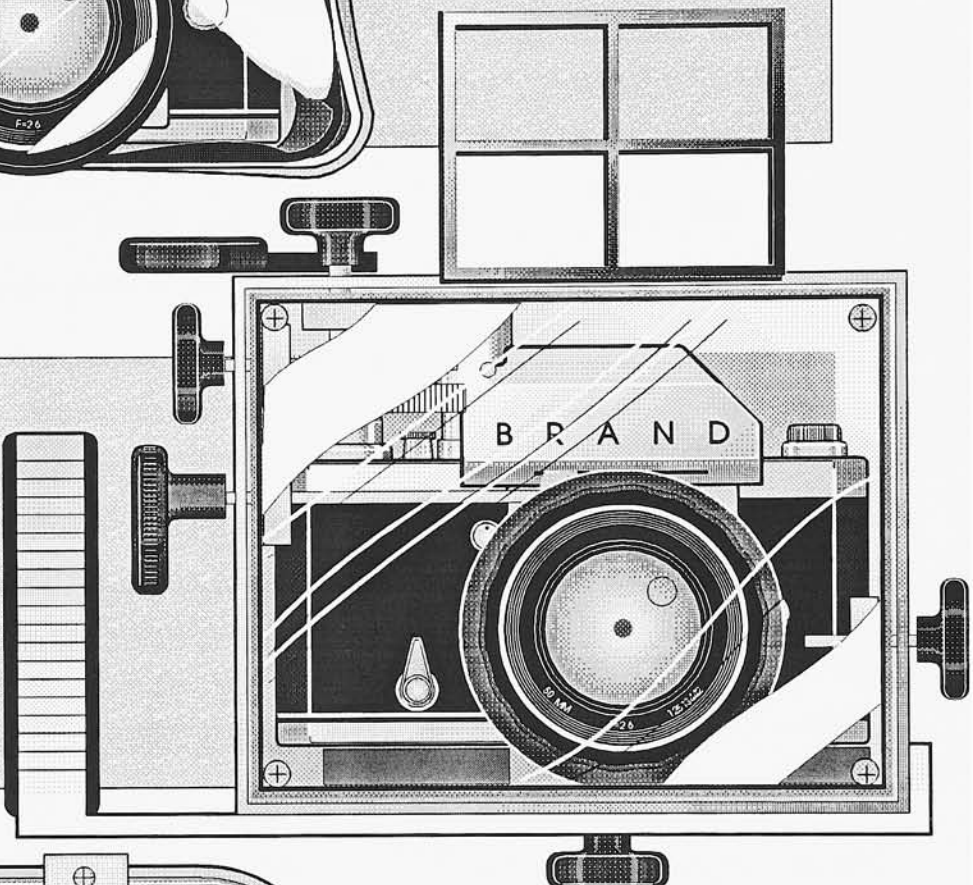
DIVE BAG

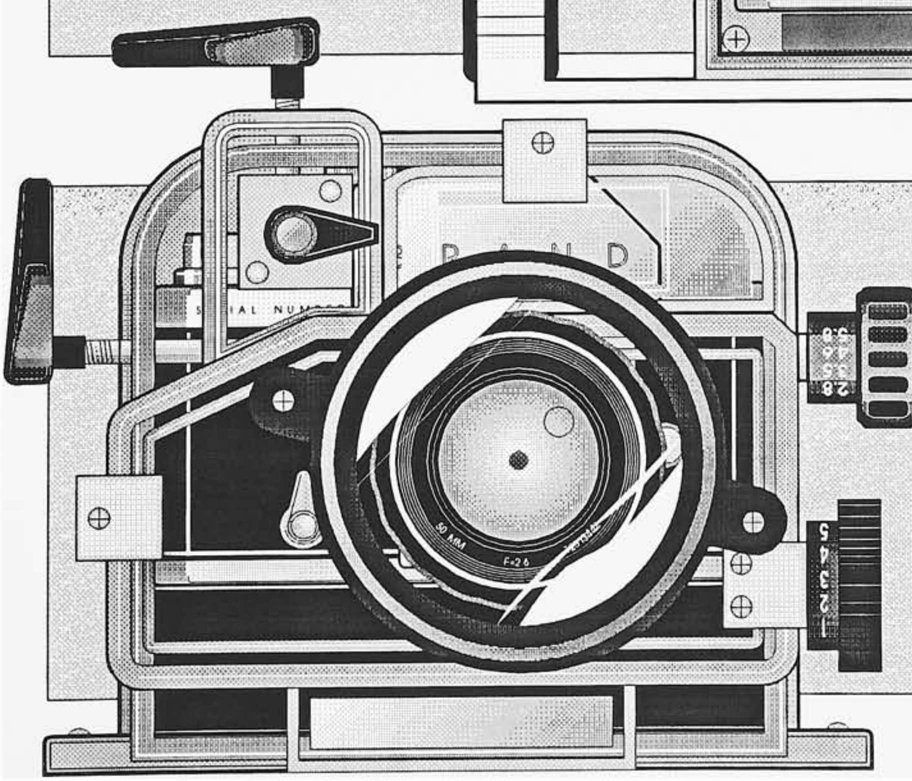


A FLEXIBLE, RESEALABLE MEMBRANE TO PROTECT AN EXISTING CAMERA FROM THE EFFECTS OF SUBMERSION IN WATER.

HOUSING

A DURABLE AND RIGID BARRIER, THAT PROVIDES MUCH MORE RELIABLE PROTECTION AND CAN BE CONSTRUCTED IN A WORKSHOP.





CASE

A FORM FITTING, MASS PRODUCED HOUSING THAT PROVIDES THE BEST PROTECTION FOR A CAMERA, WITH THE LEAST ADDED BULK AND INCONVENIENCE.

FIGURE 2.2

Unfortunately, the housing forms a secondary interface through which the camera must be manipulated. This "increases" the size of the camera and makes it substantially more complex to operate. The camera must either be manipulated through flexible membranes, as with a dive bag, or via extended controls that penetrate the housings through waterproof seals and connect to the original knobs, collars, and buttons inside. Both methods make the controls harder to operate and also render the control panel inside the camera practically useless. The camera's viewfinder can be extremely difficult to use in such devices. With housings existing cameras can be used underwater, but only indirectly and with greater difficulty.

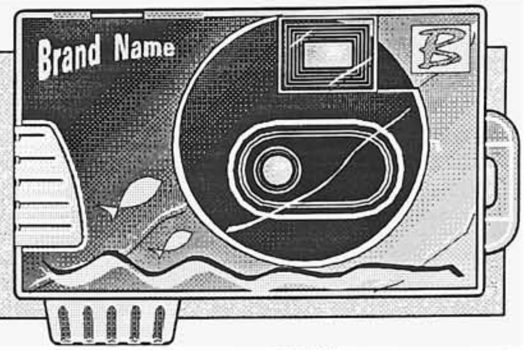
Underwater Cameras

The second class of underwater photographic equipment can accurately be called underwater cameras. Designed and manufactured to be functional underwater, they can be seen as a direct response both to the difficulty in operating a camera inside a housing, and to the large size of such units. Underwater cameras avoid the use of external housings by incorporating internal waterproof seals into every possible opening of the body to prevent water from entering while submerged. Again the standard 35 mm camera format is utilized, since the photographer supports, triggers, and views through these units in exactly the same way as on land.

Underwater cameras are definitely more compact and manageable than cameras in housings. In most cases, underwater cameras are only slightly larger than the typical land camera, and are much smaller than a housing unit. Since there is no

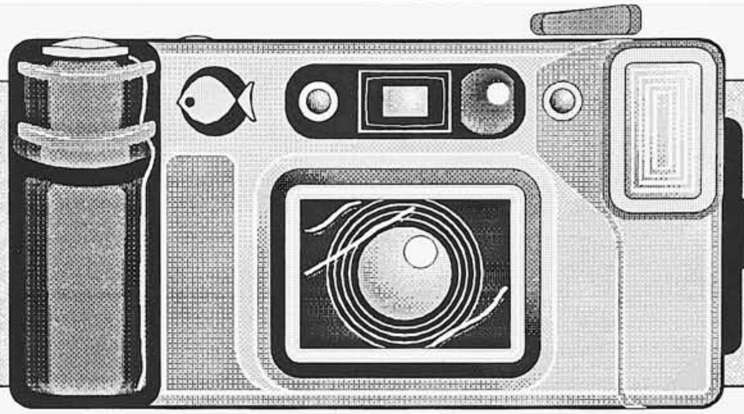
DISPOSABLE CAMERA

A SINGLE USE CAMERA THAT CAN NOT BE RELOADED. HAS PRE-SET EXPOSURE AND FOCUS. CAN BE USED ON LAND OR CLOSE TO THE WATER'S SURFACE.



POINT & SHOOT

A FULLY AUTOMATIC CAMERA. USES AUTOFOCUS IN AIR, BUT IS FIXED OR MANUAL FOCUS UNDERWATER. IT IS SUITABLE FOR HOBBYISTS POSSESSING LITTLE PHOTOGRAPHIC EXPERIENCE.



RANGEFINDER

THE MOST POPULAR UNDERWATER CAMERA. MANUAL FOCUS WITH MANUAL AND SEMI-AUTOMATIC EXPOSURE MODES. WITH EXPERIENCE CAN CAPTURE VERY GOOD IMAGES. WORKS TO VERY SUBSTANTIAL DEPTHS.

AUTOFOCUS SLR

THE MOST ADVANCED UNDERWATER CAMERA. FULLY AUTOMATED WITH AUTOFOCUS, MULTIPLE PROGRAM MODES, AND MANUAL OVER RIDES. INTENDED FOR PROFESSIONAL USE. IS EXTREMELY EXPENSIVE.

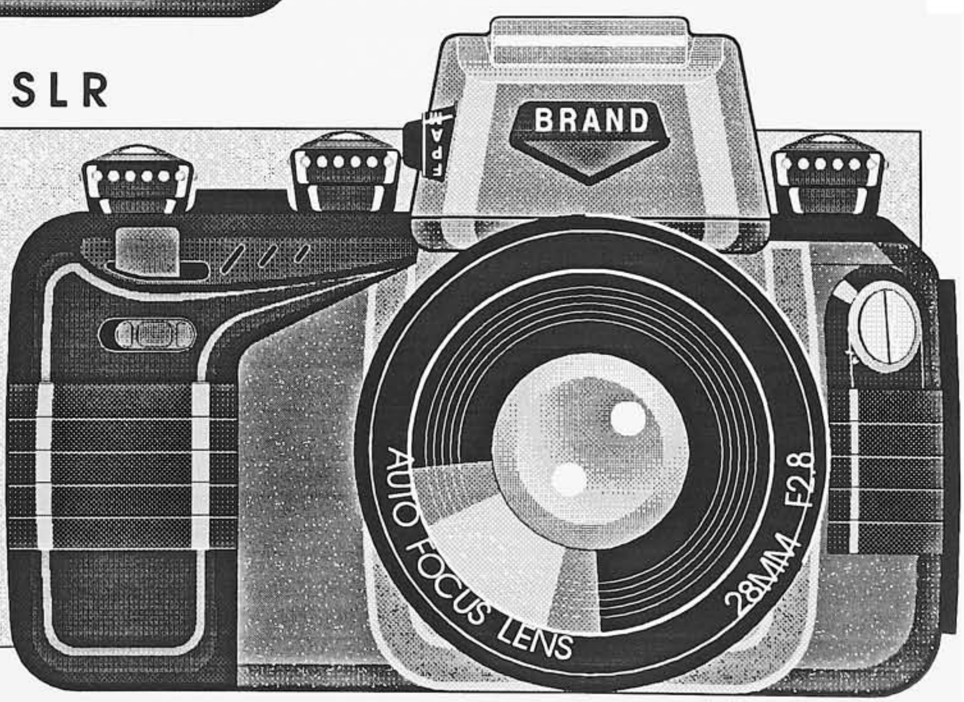


FIGURE 2.3

secondary interface involved the diver has direct access to the camera's controls.

One major reason underwater cameras retain the 35 mm land format is that this enables them to be used both on land and underwater. Technically, these cameras are amphibious, and not aquatic. When not submerged, little distinguishes them from the average camera except for their rugged appearance and unusually vibrant coloring. Underwater cameras are characteristically and necessarily more robust in construction. Since they can withstand much more abuse than regular models, they are frequently used on land as "heavy duty" or "sport" cameras.

Underwater cameras successfully avoid the obvious problems that housings cause. They allow the diver to take photographs while submerged the same way that they would on land. However, even with this advanced equipment the underwater photographer still faces substantial difficulty.

It must be reiterated that the more sophisticated and adaptable equipment in both categories can produce fantastic results for the seasoned veteran. Under certain narrow circumstances, even the most primitive equipment can give good results. However, since both underwater cameras and cameras in housings share a common format, both categories also share common problems when submerged. There are certain aspects about how land format cameras must be used in the aquatic environment that make the photographic task more complex than it needs to be, for both novice and professional divers.

The Problems with Existing Equipment

It can be difficult for divers to properly articulate what is 'hard' about using their underwater photographic equipment. This is particularly true in the case of novice underwater photographers. Having no frame of reference, it is easy for them to assume that the difficulty they are experiencing is natural and unavoidable, or the result of their own inexperience, and not due to the configuration of the equipment that they are using. But objectively, how much of this difficulty is really caused by the equipment?

Since both categories of underwater photographic equipment share the 35 mm land camera format, and since the major obstacle to underwater photography is apparently protecting the camera components from water damage, the basic rationalé behind the development of the current underwater photographic equipment seems to have been: "*How can I make this camera work underwater?*" Posing the question in this way is based upon the assumption that an existing camera will be capable of functioning properly, if only the water can be kept away from its inner workings. Such reasoning binds the designer to whatever constraints, limitations, or difficulties the existing format possesses within the new set of conditions, as well as any additional problems that the necessary adaptation may cause.

The fact that the existing equipment uses the 35 mm camera format is based on the assumption that this format is as well-suited for use underwater as it is on land. But is this true? Can the same task be performed the same way with equal ease in such different situations?

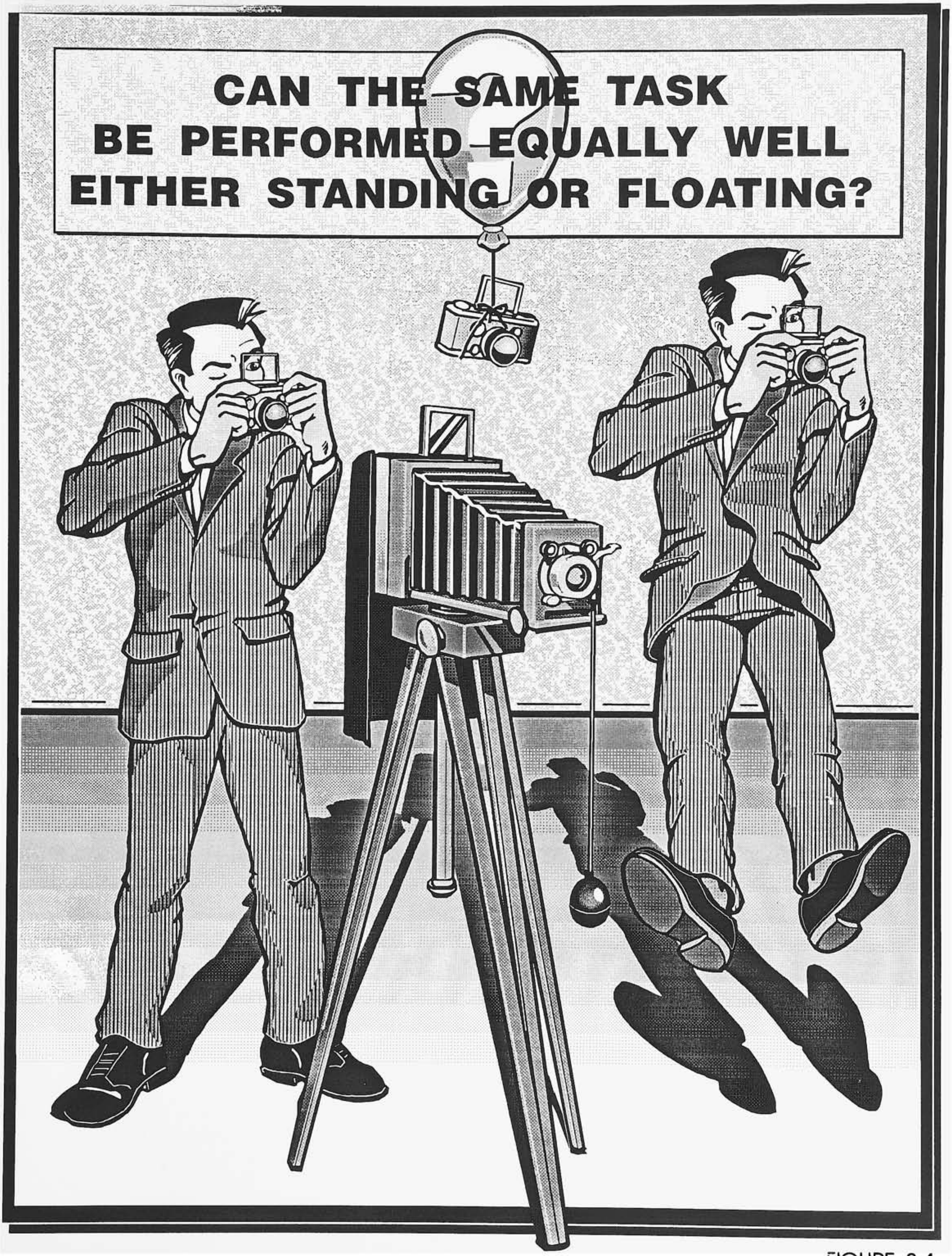

CAN THE SAME TASK
BE PERFORMED EQUALLY WELL
EITHER STANDING OR FLOATING?

FIGURE 2.4

Posture

The 35 mm camera format is ideally suited for the photographer's posture on land. Under these conditions, nothing interferes with performing the tasks required to operate the standard format camera; steadily supporting the camera for the duration of the exposure, directing it at the subject (making any appropriate settings if required), and triggering the shutter at the proper moment.

On land, photographers are most likely either standing, sitting, or kneeling in an upright position. They are firmly connected to the ground. Since most cameras are light, photographers experience little difficulty supporting or directing them properly.

A photographer can easily move around to capture any nearby subject from a variety of angles. On land, a camera does not interfere with how a person travels from place to place. If the photographer does not want to take a picture immediately, the camera can be held, worn around the neck or shoulder, or just set down to be picked up later.

Since land is a stable, "static" and non-threatening environment in most cases, photographers are in no real physical danger . The majority of their attention is free to focus on the task of capturing the desired image, while ignoring other elements of their surroundings. Most photographers can be reasonably confident that nothing will harm or interfere with them while taking pictures on land.

Underwater, the conditions encountered are almost completely the opposite. With very few exceptions *underwater photographers are practically never standing, sitting, or kneeling; they are **floating***. When floating, a body is suspended in a dynamic, fluid environment. The photographer can move in 3 dimensional space but to successfully maneuver requires fighting the currents, buoyancy and physical obstacles. With more freedom of motion in a dynamic, fluid environment it takes more effort, energy, skill, and attention *both* to move *and* to remain stationary.

Perhaps the most significant difference between the land and aquatic environments is that it is always dangerous for a person to be underwater. When submerged a diver is constantly at risk from drowning, pressure constraints, marine life, equipment failure, boats, and other unseen obstacles.

This element of danger relates to how effectively a piece of equipment can be used underwater. How well a camera functions is entirely dependent on how efficiently a person can operate it. Operating a standard format camera underwater requires a great deal of attention. Underwater, if the diver focuses too much attention on capturing the image for too long, they are taking a potentially deadly risk. Performing a complex task in a stressful environment creates an extremely dangerous situation.

How the diver moves about in the aquatic environment is completely different from how a person travels on land. Although legs are still the primary means of propulsion, hands and arms play a much more important role in moving underwater.

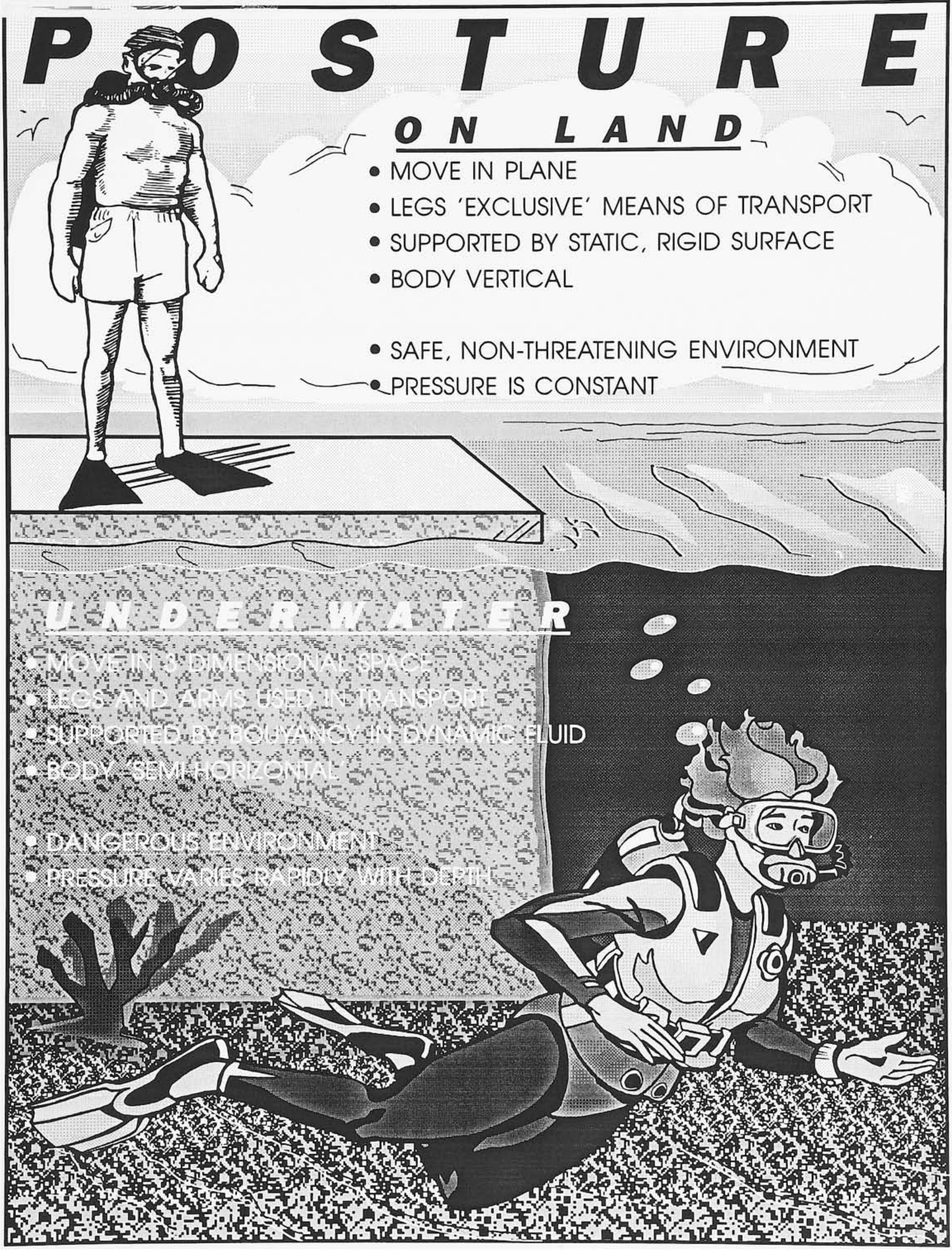

POSTURE
ON LAND
• MOVE IN PLANE
• LEGS 'EXCLUSIVE' MEANS OF TRANSPORT
• SUPPORTED BY STATIC, RIGID SURFACE
• BODY VERTICAL
• SAFE, NON-THREATENING ENVIRONMENT
• PRESSURE IS CONSTANT
UNDERWATER
• MOVE IN 3 DIMENSIONAL SPACE
• LEGS AND ARMS USED IN TRANSPORT
• SUPPORTED BY BOUYANCY IN DYNAMIC FLUID
• BODY 'SEMI-HORIZONTAL'
• DANGEROUS ENVIRONMENT
• PRESSURE VARIES RAPIDLY WITH DEPTH

FIGURE 2.5

The hands and arms are used for stabilization, maneuvering, and propulsion. They are also necessary for other tasks critical to safe diving, such as manipulating goggles, tanks, boyancy control devices, and dive computers, following guide ropes, and many other tasks.

When a camera is taken underwater, the diver must grasp it for the entire duration of the dive since there is no way to put the camera "down". Depending on its buoyancy, if the diver lets go of the camera, it might sink to a sea floor beyond reach, or it could drift away. Neither option is particularly appealing considering the great expense of the equipment. Wearing the camera around the neck or shoulders is not a viable option since the camera is bigger, may float rather than hang, and can interfere with air hoses and other important equipment. If a diver were to hand-off a heavy camera to a diving buddy while underwater the diver releasing it would float towards the surface, while the diver recieving the camera would start to sink. Each diver's buoyancy would quickly have to be readjusted to regain stability.

All these factors imply that if a camera is taken underwater, the diver is committed to hold the camera at all times. This makes the underwater photographer more of an observer than a participant; underwater photographers are extremely hampered in the non-photographic tasks that they can perform since they only have one hand available to use.

Difficulty in directing the camera underwater is dependent on both the physical maneuvers that must be performed to hold the camera in place for viewing and the difficulties of seeing through a conventional viewfinder once it is in place.

Viewing

Viewing through a standard format camera is apparently a simple task. All that is required of the user is to look through the viewfinder with one eye and compose the scene. Although this method is effective on land, it encounters substantial obstacles when it must be used underwater.

Since this task has been performed so frequently that it has almost become a reflex, it is difficult to call to mind what the standard format actually requires of the viewer. To properly see the entire area of the image within the frame of the viewfinder, the camera must be held very close to the photographer's eye. Figure 2.6 shows the positioning of the camera for proper viewing. In order to get the viewfinder close enough to the eye, the photographer's head must rotate to bring the open eye in line with the direction of the body while the open eye is rotated in its socket so that it points straight ahead. The head must be tipped down slightly. In this position, the back of the camera rests on the bridge of the nose and is very close to the cheek. When the viewfinder is a fraction of an inch from the surface of the eye, the proper position for viewing has been achieved.

On land, the contortions necessary to use the standard viewing format have minor drawbacks such as mild discomfort and eye strain. However, this method presents problems and encounters formidable obstacles when performed underwater.

Anyone who has ever tried to use a camera while wearing a pair of glasses can imagine the difficulty faced by divers trying to use a land format viewfinder

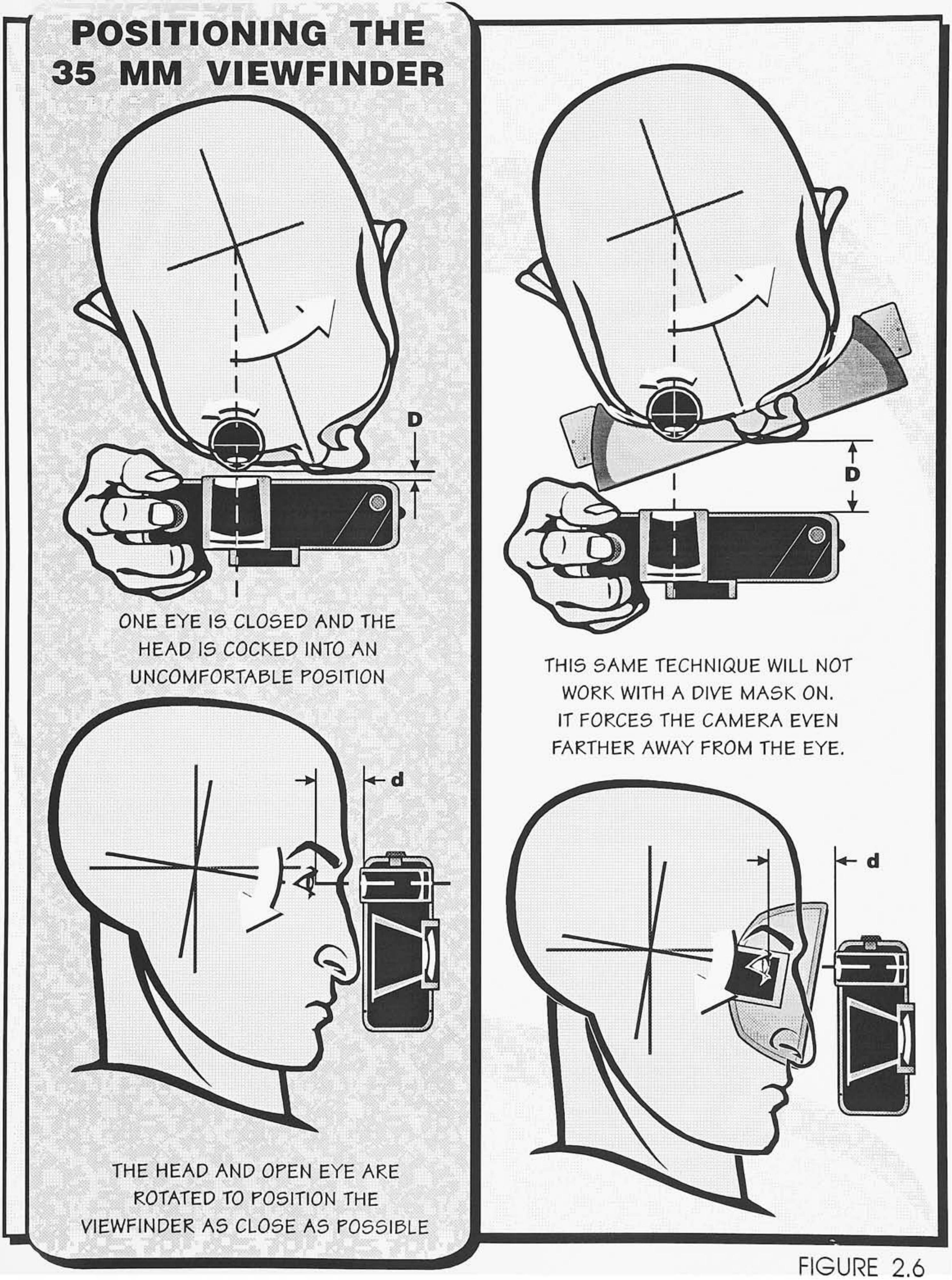
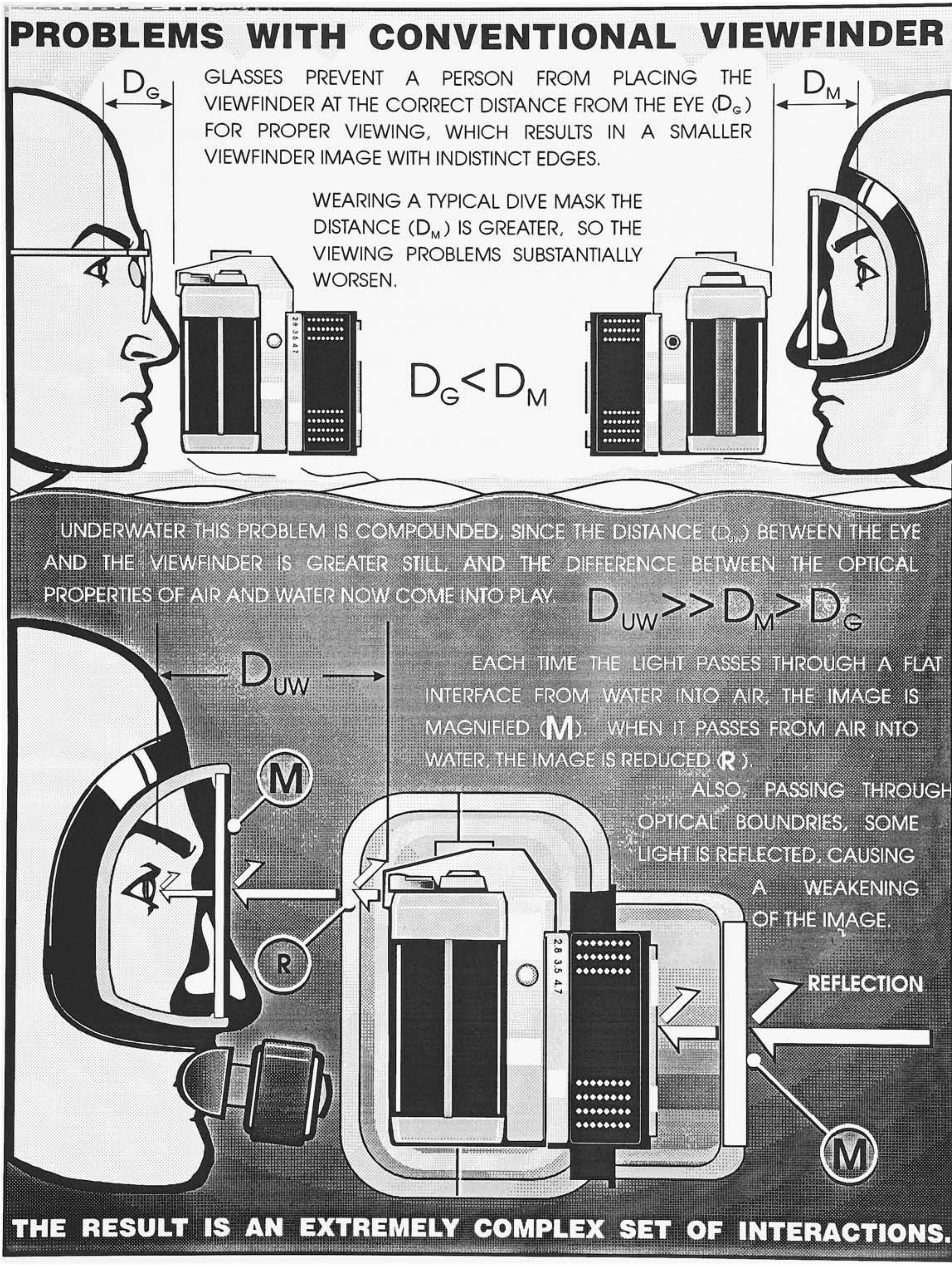

POSITIONING THE 35 MM VIEWFINDER
D
ONE EYE IS CLOSED AND THE HEAD IS COCKED INTO AN UNCOMFORTABLE POSITION
d
THE HEAD AND OPEN EYE ARE ROTATED TO POSITION THE VIEWFINDER AS CLOSE AS POSSIBLE
D
THIS SAME TECHNIQUE WILL NOT WORK WITH A DIVE MASK ON. IT FORCES THE CAMERA EVEN FARTHER AWAY FROM THE EYE.
d

FIGURE 2.6

underwater. As previously stated, glasses prevent the viewfinder from getting sufficiently close to the eye for optimum viewing, resulting in a smaller, ambiguous view of the image. The same problem occurs with a dive mask. However, since the pane of glass (port) at the front of a dive mask is located farther from the eye than the lenses of a pair of glasses, the view is even worse. The farther away from the eye the viewfinder is held, the smaller, dimmer, and fuzzier the image seen through the viewfinder becomes. Increased distance from the eye makes the viewfinder extremely difficult to use. At a certain point it becomes almost useless (FIGURE 2.7). It is physically impossible to get the land format viewfinder close enough to the eye with a dive mask on to get anything but a poor approximation of the image to be recorded.

Wearing a dive mask forces a diver to use the standard 35 mm format viewfinder differently. One eye must still be closed because the viewfinder is much too small for a person to focus through it with both eyes. Now, if the head is tipped or rotated, the dive mask increases the distance from the eye to the viewfinder. This would further reduce both the size and the usefulness of the image. To position the viewfinder as close as possible to the open eye, the diver must hold the camera's back flat against the glass port of the dive mask. With no other possible way to use the viewfinder, the diver must hope the poor view available is good enough.

Using a viewfinder underwater is also complicated by the magnification and reduction of the image (Figure 2.7). Magnification and reduction occur when light is bent by passing from one optical medium to another. Passing from water into air through a flat interface causes images to be magnified by approximately 25%.



PROBLEMS WITH CONVENTIONAL VIEWFINDER
D_G
GLASSES PREVENT A PERSON FROM PLACING THE VIEWFINDER AT THE CORRECT DISTANCE FROM THE EYE (D_G) FOR PROPER VIEWING, WHICH RESULTS IN A SMALLER VIEWFINDER IMAGE WITH INDISTINCT EDGES.
D_M
WEARING A TYPICAL DIVE MASK THE DISTANCE (D_M) IS GREATER, SO THE VIEWING PROBLEMS SUBSTANTIALLY WORSEN.
$D_G < D_M$
UNDERWATER THIS PROBLEM IS COMPOUNDED, SINCE THE DISTANCE (D_{UW}) BETWEEN THE EYE AND THE VIEWFINDER IS GREATER STILL, AND THE DIFFERENCE BETWEEN THE OPTICAL PROPERTIES OF AIR AND WATER NOW COME INTO PLAY.
$D_{UW} >> D_M > D_G$
D_{UW}
EACH TIME THE LIGHT PASSES THROUGH A FLAT INTERFACE FROM WATER INTO AIR, THE IMAGE IS MAGNIFIED (M). WHEN IT PASSES FROM AIR INTO WATER, THE IMAGE IS REDUCED (R).
ALSO, PASSING THROUGH OPTICAL BOUNDRIES, SOME LIGHT IS REFLECTED, CAUSING A WEAKENING OF THE IMAGE.
M
R
REFLECTION
M
THE RESULT IS AN EXTREMELY COMPLEX SET OF INTERACTIONS.

FIGURE 2.7

Depending on the geometry of the interface, when light passes from air to water, the image is reduced. To further confuse matters, every time light passes from one medium to another, some of the light is reflected back, slightly weakening the signal that does pass through the boundary. The interaction of magnification, reduction, and reflection all contribute to an extremely complicated set of interactions that directly affects viewing underwater.

If a diver is using a camera in a housing with a flat front port, the image seen through the viewfinder has first been magnified as it crosses into the housing, reduced as it leaves, and is magnified again as it enters the dive mask. Each crossing makes the signal weaker. By the time the light reaches the diver's eye it has diminished in intensity to some degree because of the many optical boundaries it has crossed. It has become larger, dimmer, and fuzzier. How closely the view that the diver can see through the viewfinder corresponds to the image actually recorded on the film is extremely difficult to say, although, considering all the factors involved—magnifications and reductions, loss of image intensity due to reflections, and decreased image size—it is most likely a very rough approximation.

The complexity of this series of interactions prompted the development and use of the "sports finder" on many housing units and underwater cameras. A sports finder is usually a simple bent wire or plastic frame that can be used to approximate the image to be recorded on film. Even though on land a sports finder is a much less accurate viewing device than the standard viewfinder, it is widely used underwater because it has no optical boundaries to cause magnification or reduction.

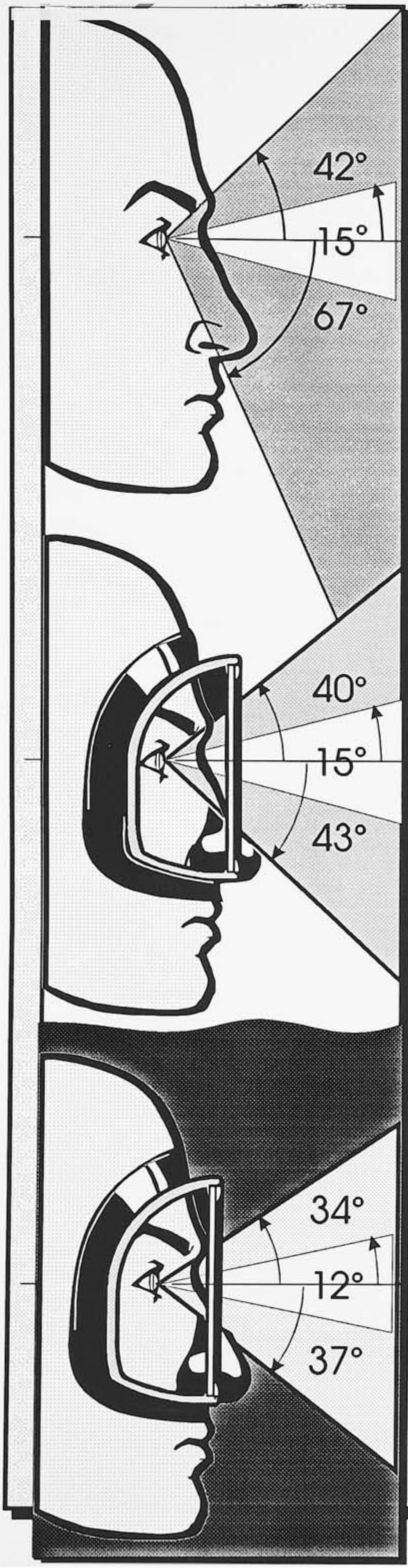
The optical properties of water have further consequence to the diver. Underwater, the dive mask defines the extent of the diver's field of vision. Figure 2.8 shows the limitation of the diver's field of view caused by a dive mask. In air, with no optical obstructions, a person's field of view is quite wide, with a fifteen degree cone of sharpest vision in the center of the field (Woodson, 1981, 826, 827). Adding a dive mask, this field is constricted by the sides of the mask. The outer most part of the field's perimeter has been removed, although the central cone of vision is not affected. Underwater, magnification results in both a further reduction of the diver's overall field and a reduction of the central cone. The net result is that while submerged, under the optimum conditions, a diver can only use a fraction of the total field of vision.

The reduction of the diver's field of view is an inevitable consequence of using a dive mask, and further complicates the use of standard viewfinders underwater.

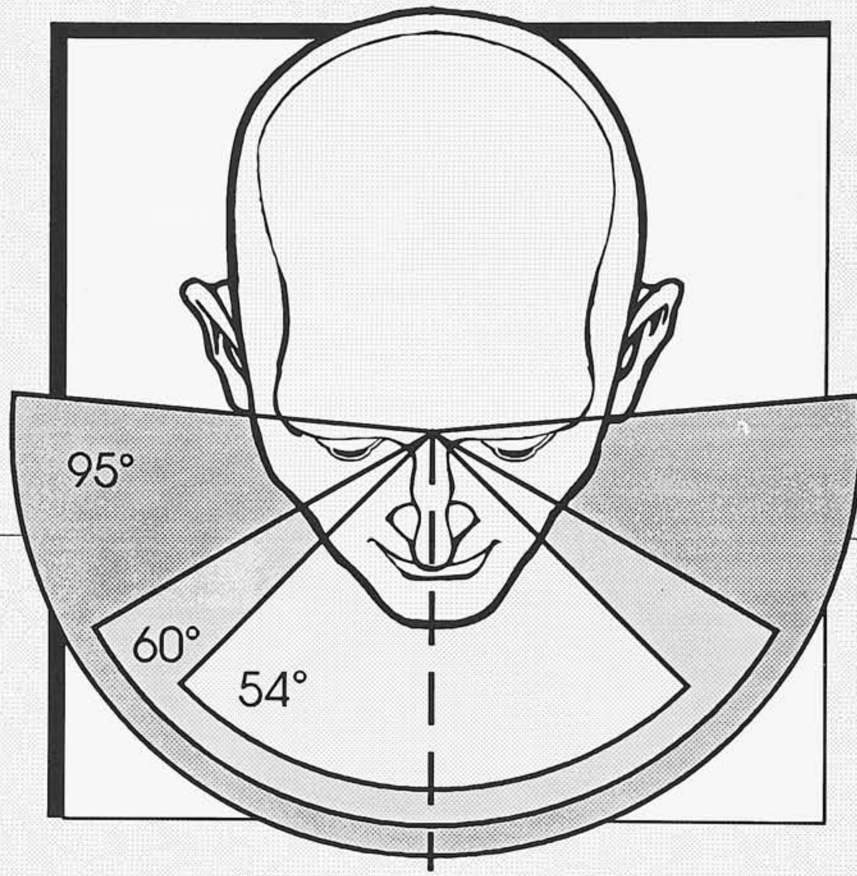
The top panel of Figure 2.9 illustrates the diver's field of view as seen through a typical dive mask. Using an underwater camera dramatically reduces this field. When the diver closes one eye to use the viewfinder, approximately 40% of the initial field of view is lost. Since the brain requires views from both eyes to construct a stereoscopic image, the resulting view is myopic and all sense of depth perception is lost.

Holding a camera up to the face mask and looking straight ahead through the viewfinder, the myopic field is further reduced, as in the middle panel of Figure 2.9.

DIVER'S FIELD OF VIEW



IN AIR, A PERSON HAS A WIDE FIELD OF VIEW*. A 15 DEGREE CONE OF SHARPEST VISION IS LOCATED IN THE CENTER OF THE FIELD. PERIPHERAL VISION SURROUNDS THIS CENTRAL CONE. PERIPHERAL VISION IS NOT AS SHARP AS IN THE CENTRAL CONE, BUT IT CAN DISTINGUISH BRIGHTNESS AND MOTION AND GIVES A SENSE OF THE SURROUNDINGS AND WARNS OF IMPENDING DANGER.



IN AIR, A DIVE MASK DOES NOT INTERFERE WITH THE CENTRAL CONE OF VISION. IT BLOCKS OUT A SUBSTANTIAL PORTION OF THE SIDES AND BOTTOM OF THE FIELD OF VIEW.

UNDERWATER BOTH THE CENTRAL CONE AND REMAINING FIELD ARE REDUCED 80% BY THE 25% MAGNIFICATION EFFECT CAUSED BY THE FLAT PORT OF THE DIVE MASK. THIS IS A SIGNIFICANT DECREASE IN THE FIELD OF VIEW.

CONSEQUENTLY, IN A STRANGE AND DANGEROUS ENVIRONMENT, DIVERS MUST RELY ON A SMALL FRACTION OF THEIR FIELD OF VIEW.

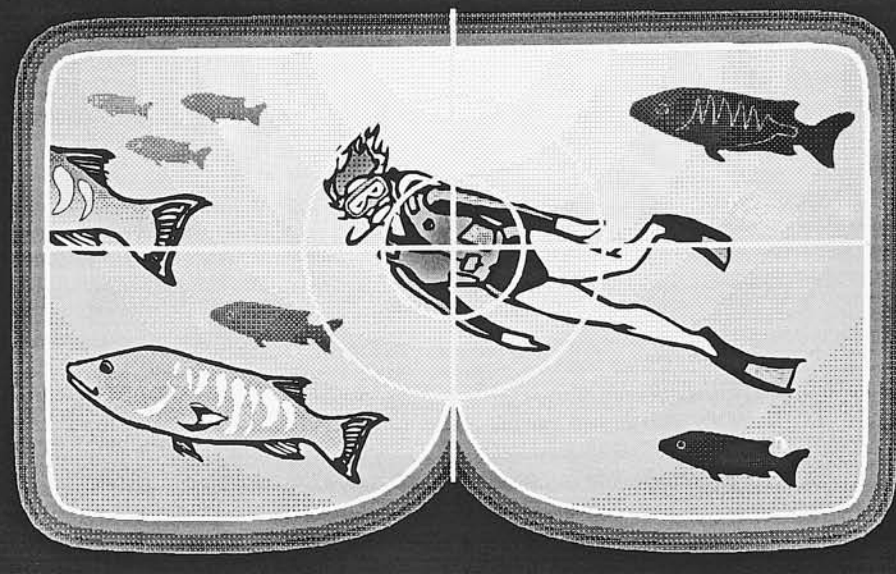
* WOODSON, 1981

FIGURE 2.8

THIS FIGURE SHOWS THE FULL FIELD OF VIEW AS SEEN THROUGH A DIVE MASK.

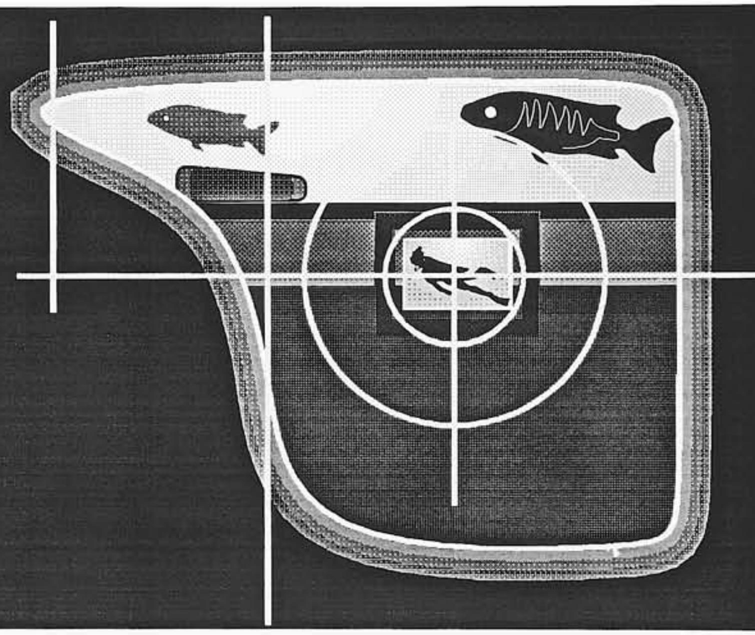
THE INNER CIRCLE SHOWS THE 15 DEGREE CONE OF SHARPEST VISION, AND THE OUTER CIRCLE SHOWS A 30 DEGREE CONE.

THE EXACT EDGES OF THE FIELD OF VIEW ARE FUZZY AND INDISTINCT.



USING AN UNDERWATER CAMERA, THE DIVER CLOSES ONE EYE, RESULTING IN A SEVERE REDUCTION IN THE FIELD OF VIEW. DEPTH PERCEPTION IS ALSO LOST, RESULTING IN A MYOPIC VIEW.

LOOKING THROUGH THE VIEWFINDER THE DIVER'S VISUAL FIELD IS FURTHER REDUCED. THE AREA OF THE VIEWFINDER IS EXTREMELY SMALL COMPARED TO EVEN THE MYOPIC FIELD. MOST OF THE DIVER'S FIELD OF VIEW IS BLOCKED BY THE BACK OF THE CAMERA.



IF A SPORTSFINDER IS USED INSTEAD OF THE VIEWFINDER, THE VIEWING AREA IS INCREASED. HOWEVER, WITH ONE EYE CLOSED, THE FIELD OF VIEW IS STILL REDUCED AND OBSCURED BY THE BACK OF THE CAMERA.

UNDERWATER, THE APPROXIMATION OF THE IMAGE TO BE PHOTOGRAPHED GIVEN BY THE SPORTSFINDER IS MUCH LESS ACCURATE THAN THE ONE GIVEN BY AN AVERAGE VIEWFINDER IN AIR.

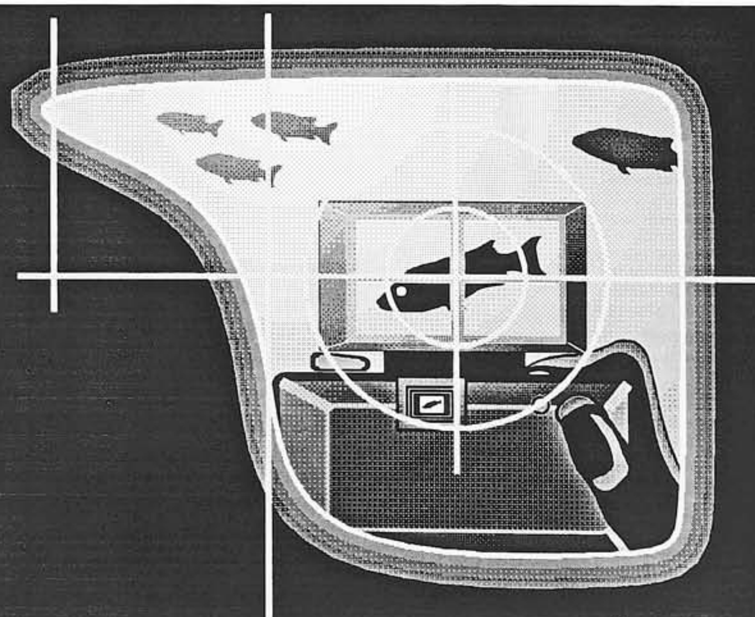


FIGURE 2.9

Only the small viewfinder image, plus a fraction of the peripheral vision above the top of the camera can be seen. The majority of the field of vision is obscured by the back of the camera and is unusable. Holding the camera farther away from the mask increases the peripheral vision, but reduces the usefulness of the viewfinder.

Even looking through a sportsfinder, as in the bottom panel of Figure 2.9, a large portion of the view remains useless, although more of the diver's peripheral vision is salvaged.

Therefore, utilizing the standard 35 mm camera format underwater assures that only a very tiny portion of the diver's field of vision is usable in a highly dangerous, alien environment that requires undivided attention.

Results

Poor image quality is not *necessarily* a result of using the standard 35 mm land camera format underwater. There is little about a camera's format, besides film size, that directly affects the photographic qualities of the images obtained. The quality and versatility of the camera's focusing and exposure systems, and the persons or devices that control these systems, determine the caliber of the images recorded. These systems vary dramatically from model to model within the 35 mm format.

Nevertheless, the reasoning behind using the 35 mm camera format underwater does affect the optical results. The focus on preventing water damage to an existing photographic system causes the differences between the optical properties of the old and new environments to be virtually ignored. The properties of water are so radically different from those of air that many cameras, designed for a wide range of situations on land, function poorly, if at all, underwater—even when protected by the most expensive cases.

A camera designed to be used underwater cannot disregard the optical properties of water, and consistantly produce satisfactory images. The optical properties of water greatly affect what can be seen and what can be recorded. Water is much more dense than air. Although it is possible to see objects in air at a distance of several miles on a clear day, underwater the maximium visibility is little more than ninty feet (visibility underwater can quickly change, even dropping to zero).

Besides magnification and reduction, the properties of water that most significantly affect photographic results are the color shift due to the absorption of most wavelengths of visible light and the decrease of image contrast.

Filters absorb certain colors of light; the thicker the filter, the more color is removed. Water acts as liquid filter and absorbs ultraviolet, infrared, and most of the visible spectrum passing through it. Blue and green represent the wavelengths that are the least absorbed, and most easily transmitted colors of light. The volume of water that light must pass through affects the degree of the filtering of different colors. For this reason, color shift becomes more pronounced in deeper water where only the blue light from the surface can penetrate. Color shift also increases with the distance between photographer and the subject. This is unavoidable and must be expected.

Contrast Reduction and Exposure

The particles and microscopic creatures suspended in the water that can cause so much damage to the camera's components also decrease optical contrast, resulting in a dulling of the image. Optically, being underwater is like being in a room full of smoke; the space is full of floating particles that obstruct and convolute the light's path. The lightwaves that carry an image travel along a path between the subject being photographed and the camera's lens. Some of these waves strike particles moving through the path and are reflected away from the camera, making the bright areas of the picture dimmer. Other ambient light, not associated with the image, may strike particles along the path and be reflected towards the lens, making the areas of shadow in an image brighter. The combined result of both these interruptions is dimmer highlights and brighter shadows; reduced image contrast.

The more particles that are suspended in the water, the greater this effect becomes. Reduction of contrast becomes increasingly significant in deeper and poorly-lit waters, since under these conditions the ambient light is less intense, so there is less contrast to begin with. Little can be done to prevent this loss.

For this reason contrast is always less underwater than in equivalent situations on land. Since the number of particles increases with the volume of water between the diver and subject to be photographed, optical contrast decreases rapidly with distance. The farther the distance the fuzzier and less distinct the image becomes. This is one reason why the background in underwater photographs does not contribute much to the picture besides murky blue depth.

Most land exposure systems use light from both the subject and large areas of the background to determine the proper exposure for a photograph. Simple systems use a single light sensing diode that in effect takes an average reading of the light across the entire area of the image. The result is a weighted average reading of the intensity of all the light reaching the sensor. This method assumes that if you expose to make the average intensity 50% gray, the areas of highlight and shadow will naturally fall into place.

On land this method works well because there is almost always distinct areas of highlight and shadow. Underwater, a scene may be equally well lit, but possess a much narrower range of contrast. For example, under brighter conditions with


CONTRAST AND RESULTS UNDERWATER
CREATURES AND PARTICLES SUSPENDED IN THE WATER OBSTRUCT THE PATH OF LIGHT WHICH DECREASES CONTRAST UNDERWATER.
THE FARTHER AWAY AN OBJECT IS, THE GREATER THE VOLUME OF WATER ALONG THE PATH, AND THE LARGER THE NUMBER OF PARTICLES PRESENT.
BRAND
NAME
MISCELANEOUS INFORMATION
ISO
SELF
ISO
REW.
THE EXPOSURE SYSTEM OF A TYPICAL POINT & SHOOT CAMERA DOES NOT FUNCTION WELL UNDER WATER.
SUCH SYSTEMS USE A SIMPLE SENSOR TO READ THE LIGHT ACROSS THE ENTIRE AREA OF THE IMAGE TO DETERMINE EXPOSURE. THE CONTRAST FROM OBJECTS IN THE FOREGROUND CAN BE GOOD. BECAUSE THEY ARE CLOSE THERE IS LITTLE INTERFERENCE. HOWEVER, THE 'LOW CONTRAST' LIGHT FROM THE BACKGROUND GREATLY OUTWEIGHS THE SUBJECT, RESULTING IN OVEREXPOSED OR UNDEREXPOSED PHOTOGRAPHS.
BY EXPOSING FOR THE SUBJECT AND NOT THE BACKGROUND, THIS PROBLEM CAN BE LARGELY AVOIDED.

FIGURE 2.10

reduced contrast, the average intensity of the light composing the picture could be 60 or 70% gray; if the camera reads this intensity and exposes the film to render the image 50% gray, the resulting picture will be underexposed and appear dark when viewed. In dimmer situations, the average intensity could be 40% gray or less; again a simple exposure system will expose to render the image 50% gray; it will overexpose the image. Underwater, factoring in large areas of the background in determining the light readings directly results in 'drowning' the subject in homogeneous murk. The resulting image is improperly exposed for both subject and background.

For underwater purposes the most important light reading comes directly from the subject. The subject is usually much closer to the photographer than the rest of the picture, and consequently has the best range of contrast in the image. Most sophisticated underwater cameras have lightmeters that either read a very small center spot of the image (spotmeter), or use an array of sensors (matrix metering) to properly detect different lighting situations. Cameras with manual exposure modes allow photographers to compensate for their lightmeters' inadequacies based on their own previous experience. However, simple automatic cameras possess no overrides and will consistantly be fooled and expose poorly every time the situation arises.

Lenses and Focusing Systems

The choice of lens and focusing mechanisms an underwater camera uses also effect the quality of the results. Unfortunately, the most successful focusing strategies all encounter serious problems underwater.

Manually focused cameras present the diver with two alternatives; either they must look through the viewfinder to focus or they must accurately approximate the distance to the subject and set the lens accordingly. Unfortunately both methods pose problems. Because of the optical properties already discussed, it is extremely difficult to see if the subject is in focus through the viewfinder, and, because of the magnification of the dive mask, it can be equally difficult to approximate the distance to the subject. In either case, much guesswork is involved.

When an object is in focus, distinct areas of highlight and shadow are projected on film; if it is out of focus, these areas are blurry and blended together. Many sophisticated autofocus Single Lens Reflex cameras use contrast in this way to determine if an image is in focus or not. Depending on the contrast level, such a system could work underwater. In low contrast situations a manual focus mode is still necessary on such cameras.

Most point-and-shoot land cameras use infrared beams to autofocus. In this system, the camera emits a beam which bounces off the subject and returns to the sensor. The intensity of the returning beam corresponds with the distance traveled, allowing the camera to focus the lens. This scheme simply will not work underwater.

Water *absorbs* infrared light. Underwater, even at short distances, the strength of an infrared signal returning to the camera would be much less than on land because of ports, cases, and the absorption of the signal. An autofocus camera in this situation would interpret the subject as much farther away than it actually is. This problem is why most point-and-shoot underwater cameras default to a fixed-focus mode underwater; their autofocus systems function but are completely inaccurate.

When an autofocusing system is set to a fixed-focus mode, the results are not as clear as they could be if taken with a well-designed fixed-focus system.

Point-and-shoot cameras usually have a mildly wide-angle focal length lens. By allowing point-and-shoot cameras to be submerged, the diver is hampered by a poor choice of lens focal length. Underwater, wide angle lenses are much more effective than "normal" lenses, since they have greater depth of fields and wider field of views. Greater depth of field means that more of the picture is in focus and makes focusing easier since there is a larger margin of error. Wider field of views makes objects seem smaller and farther away. This counteracts the effects of magnification caused by the flat ports on the front of the camera. The result is that objects appear more natural. Furthermore, by making objects seem farther away, wide-angle lenses act to "minimize" the apparent amount of water between the camera and the subject. All of these factors lead to apparently sharper, clearer images.

Summary of Results

Simple automatic cameras are dependent on how well the conditions they will encounter have been anticipated. By enabling a land-format automatic camera to take pictures underwater (using a case or seals), it is being allowed to function outside the range of situations it has been designed to successfully deal with. Less-than-optimum images captured are the inevitable results. On more complex cameras, and ironically on simpler manual cameras as well, the conditions encountered underwater are better handled by their respective controllers: microcomputers and personal experience. However, the control interfaces of both these types of cameras are not easily manipulated underwater, and this can also substancially decrease the quality of the images obtained.

Better images could undoubtedly be obtained from some other kind of underwater camera in a safer, more stress-free, and less frustrating way if the camera was designed specifically for the situations encountered underwater.

CONCEPT

Having explored the problems of posture, viewing, and image quality that are caused by using the conventional 35 mm cameras underwater, we have seen that, although it provides an extremely useful tool, this format is not ideally suited to use underwater. With this in mind, the question arises, are these obstacles the inevitable results of trying to take photographs underwater, or are they uniquely caused by the over-extention of this particular format? If these problems are not inevitable, what can be done to avoid them?

Based on the exclusive use of the 35 mm camera format, the rationalé behind the development of conventional underwater photographic equipment has been, "*How can I make this camera work underwater?*" Such a line of thought is very limiting. It naturally leads to housings and protective seals which carry problems that do not aid in taking pictures underwater. But by re-formulating the basic question, can the development be freed from the constraints of conventional equipment?

Why not ask "*what kind of camera do I need to take pictures underwater?*" This second question is based on a new rationalé that is fundamentally different and does not share the same constraints. Now it is the results that are important; the focus is on capturing the images by any means possible. Any configuration capable of recording the desired image underwater is a perfectly valid solution.

However, this question is not quite specific enough for design purposes. Since the root of the task is to take a photograph underwater, and to do this some kind of camera is definitely needed, the question becomes "*What kind of underwater camera should I use to record the best possible images, in the safest, most natural way, with the least stress and physical demands?*"

This new rationalé makes it possible to develop a variety of alternate camera formats, appropriate for the unique physical and optical conditions of an aquatic environment.

New Format Formulation

What should the new format be like to minimize the problems inherent in the existing equipment? A camera's size and shape help to determine how it must be supported and operated. All of these attributes characterize the camera's format and constitute the interface between photographer and mechanism. Neither the photographer nor the camera mechanisms can be eliminated without losing the ability to record an image; however, the interface between the two can certainly be reconfigured.

This will require developing new ways of supporting and operating the camera's mechanisms and creating new shapes and forms that are appropriate for the conditions that diver and camera will realistically encounter underwater. By evaluating the problems of the existing equipment, clues can be obtained that will help to create a new format free from such limitations.

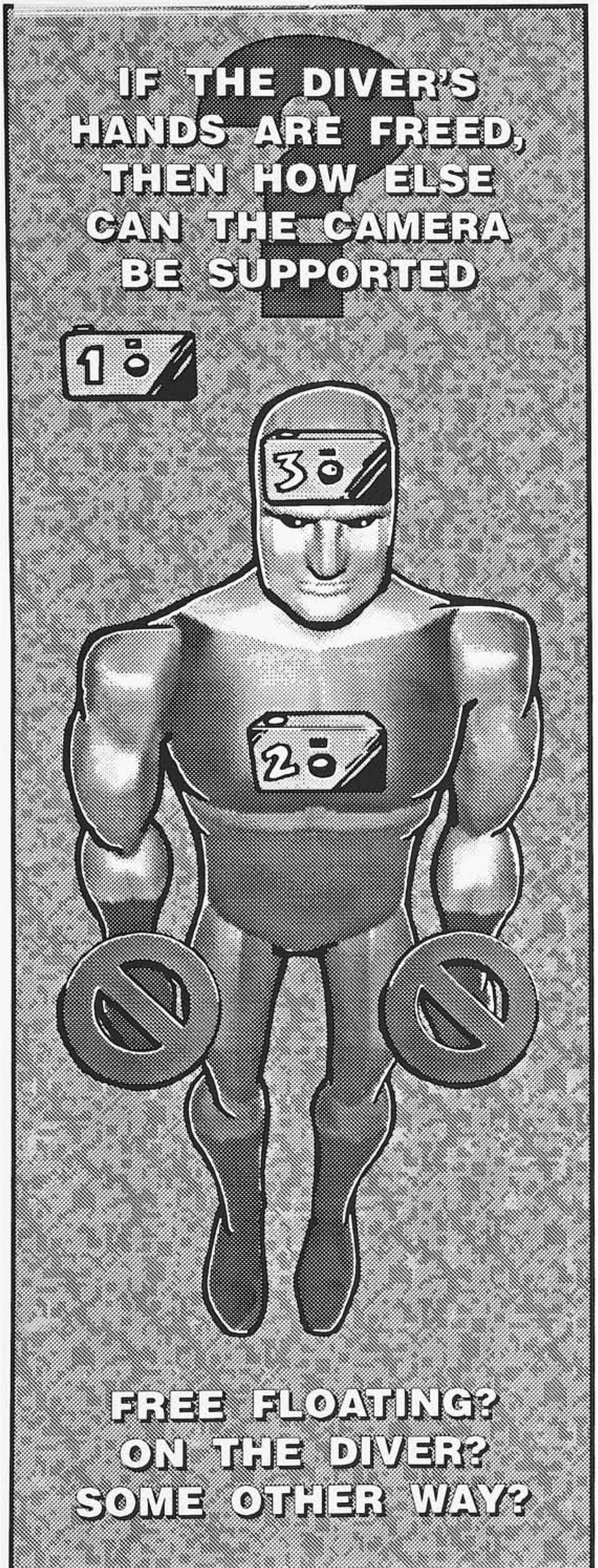

IF THE DIVER'S
HANDS ARE FREED,
THEN HOW ELSE
CAN THE CAMERA
BE SUPPORTED
1
3
2
FREE FLOATING?
ON THE DIVER?
SOME OTHER WAY?

FIGURE 2.11

Divers may experience increased difficulty moving through the water and maintaining position when forced to hold on to a camera for the duration of their dive. Holding a camera definitely affects their ability to move freely in the aquatic environment. Nevertheless, if the diver wants to record an image, the camera must be supported.

Is it possible to free the diver's hands by supporting the camera some other way? Eliminating the use of hands, several alternate means of support immediately spring to mind.

Perhaps the camera could support itself. A neutrally buoyant camera, with remote control navigational systems could follow behind like a loyal dog, and come to the diver when signaled. It could also be mounted on the air tank and be remotely controlled to follow the diver's head movements. But both of these alternatives, regardless of their novelty and other potential merits, substantially increase the complexity of the device, which in an unforgiving environment is courting trouble. Although they free the diver's hands they do very little to address the other problems of the old format.

If the diver cannot hold the camera, then the simplest solution is that the camera should grasp the diver. The camera could easily be fastened to the head or body, eliminating any active effort to support it. In fact, considering vest, tank, fins, hoses, mask, and dive computer, the underwater camera is perhaps the only piece of diving gear that is not already fastened to the diver.

One possibile way to do this is to strap the camera to the diver's chest. As strange as it seems, this means of support has actually been used in the past when gamblers and spies concealed small, flat cameras with lenses that were disguised as buttons underneath their vests. However, a diver would have significantly more difficulty using a camera fastened to the chest than a person on land. Since the diver is typically floating in a semi-horizontal posture, the body usually, but not always, points in an entirely different direction than the head. Mounting the camera in this way would require a great deal of adjustability. A diver would have to look down at the camera to point it in the proper direction; viewing and operating such a unit would be extremely difficult.

By far the *easiest* way for the camera to be pointed in the same direction as the diver's head is for it *to be fastened to the diver's head*. Conventional cameras need to be held up to the eye, so instead of moving the camera up to the eye and then back down every time a picture is to be taken why not just keep it there? With this method has two major advantages. The diver's hands are freed from having to hold any equipment and, like the light on a miner's helmet, the camera automatically follows the diver's head with no extra effort.

The camera could be attached to the dive mask as a separate unit, or it could be built into the mask. Just attaching the unit to a mask would be difficult since individual dive masks vary greatly in size and shape, they could easily be misaligned, or the unit could fall off underwater. A permanantly connected unit would be far superior in stability, security, and accuracy. In either case, there are a limited variety of ways to connect the camera to the dive mask. The camera could be mounted above the dive mask, to the side, or underneath; or it could rotate down into place when needed, like the visor on a knight's helmet. Which one of the many options presents the most advantages is not immediately clear.

Examining the trouble with conventional viewfinders provides a indication how best to fasten the camera to the head. If the new solution does not address this difficult and hazardous process it would be no better than the existing equipment.

The difficulty in viewing is caused by the inability of the diver to position the small viewfinder sufficiently close to the eye, because of the dive mask . The camera's viewfinder roughly blocks out the portion of the view that will be recorded on film, by restricting the diver's field of view. Unintentionally, the dive mask also limits the diver's field of view. Since these two devices are doing similar things in the same space, they interfere with each-other. Why not combine the two conflicting elements into one? If the port approximates the view of the lens, the viewfinder is redundant. Allowing the port to do the job of the viewfinder would completely eliminate the conflict. The diver's field of view would no longer be further restricted when taking a photograph. Eliminating the viewfinder would actually reduce the overall amount of equipment needed.

The viewfinder can be eliminated by ***integrating*** *the camera into the dive mask.* This creates a new camera format that frees the diver's hands, is as stable as the diver and does not restrict movement or the tasks that can be performed. It *completely* eliminates the problems caused by the interference of the viewfinder and the port.

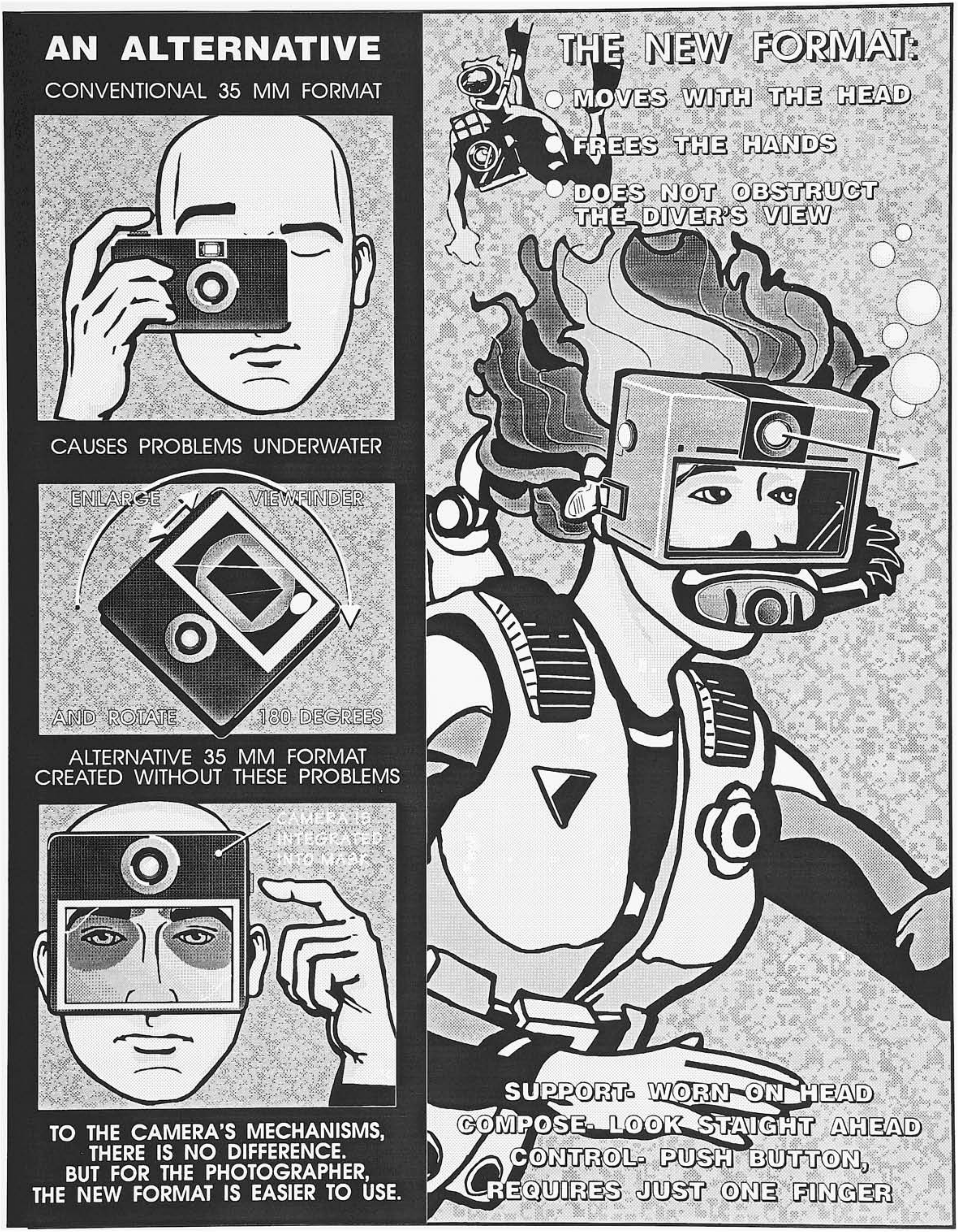

AN ALTERNATIVE
CONVENTIONAL 35 MM FORMAT
CAUSES PROBLEMS UNDERWATER
ENLARGE VIEWFINDER
AND ROTATE 180 DEGREES
ALTERNATIVE 35 MM FORMAT
CREATED WITHOUT THESE PROBLEMS
CAMERA IS
INTEGRATED
INTO MASK
TO THE CAMERA'S MECHANISMS,
THERE IS NO DIFFERENCE.
BUT FOR THE PHOTOGRAPHER,
THE NEW FORMAT IS EASIER TO USE.
THE NEW FORMAT:
MOVES WITH THE HEAD
FREES THE HANDS
DOES NOT OBSTRUCT
THE DIVER'S VIEW
SUPPORT- WORN ON HEAD
COMPOSE- LOOK STAIGHT AHEAD
CONTROL- PUSH BUTTON,
REQUIRES JUST ONE FINGER

FIGURE 2.12

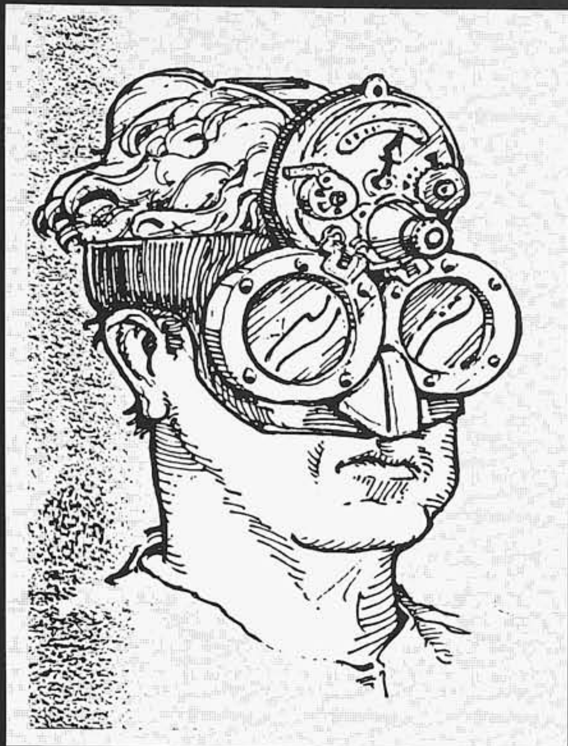
Feasibility

Size is the major factor in successfully being able to mount a camera on a person's head. Since small cameras have been present almost since the beginning of photography the idea of combining a camera with a dive mask has been technically feasible for a long time (Figure 2.13). However, the adaptability, ease of use, and image quality of earlier compact cameras, as well as the lack of adequate reusable waterproofing material would have made such a design impractical. The image quality from modern compact automatic cameras is approaching a 'professional' level of excellence, as refined programs and elaborate sensors become increasingly versatile and small. This makes the concept of integrating a 35 mm camera into a dive mask an extremely viable option, without producing a device as large as and more cumbersome than a Viking helmet.

Modern electronics, with a properly designed program, can yield optimum results without making complex demands on the photographer.

There are several questions that need to be addressed in order to establish this new concept's viability. Will this new arrangement be too difficult to operate? Can the dive mask really do the same job as the viewfinder?

As to whether the new format will be too difficult to operate, it is important to keep in mind that with the standard format the hands must hold the camera in place, and operate it. Those are two distinct and unrelated functions; the camera does not need to be hand-held to be operated. (If it did then it could not work on a tripod.) If



A 19TH CENTURY COMPACT CAMERA COULD HAVE BEEN INTEGRATED INTO A PAIR OF GOGGLES.

THERE WAS PLENTY OF ROOM FOR A CAMERA IN/ON AN OLD-FASHIONED DIVING HELMET.

FIGURE 2.13

we remove the diver's obligation to support the camera, eliminating one of the tasks, it is unlikely that the remaining task will become more difficult, from the standpoint of ease of manipulation.

If settings were required to be made with the integrated format camera, would this be more difficult because the camera is attached to the face? The option of looking at the front or top of the camera, where the controls and settings are usually displayed on existing underwater equipment, is impossible with the new format—the diver would have to take off the mask to set the controls. However, this criticism is not as valid as it may initially seem. Even on land with a traditional format camera, most settings are intended to be made while looking through the viewfinder. That is why there are usually control panels within the viewfinders; looking at the knobs and buttons is a secondary system, for use when it is difficult to use the primary system. Underwater cameras have oversized, boldly labeled controls on their bodies because the camera cannot be held close enough to the eye to see the fine details of the control panels within the viewfinder; with this equipment the secondary system becomes the only option.

By maximizing the viewfinder in the new format camera, with thoughtful placement of the necessary control panel and a sensitive placement of the controls, the task of operating the camera should become much easier, not more difficult. A new primary system that is accessible can be created.

If a lens is chosen for the new unit with a focal length that gives the camera approximately the same field of view that the diver has, and if these fields are properly aligned, then everything that the diver sees will be within the field of view of the camera. This way the diver does not have to worry about composition or the exact placement of the subject within the viewfinder. If it can be seen, it can be recorded.

Is the existing underwater photographic equipment appropriate for underwater use? Not really. It may work well under certain circumstances with clever handling, but there is little about the configuration, or results that indicate it is well-suited for use underwater. In fact, most distinguishing characteristics show a near complete disregard for the actual conditions that are encountered underwater. Are the frustrations and difficulties faced with these devices inevitable? Apparently not. There is every indication that a unit designed to be sensitive to the factors intimately and unavoidably involved with the reality of underwater optics and motion could easily avoid the problems plaguing more traditional equipment.

DEVELOPMENT

In the previous sections, the reasoning behind the development of a new camera format that integrates a camera into the housing of a dive mask was established. In this section a new camera will be developed to represent this format.

Just as the 35 mm land format encompasses a wide range of cameras, the new aquatic format can support a wide array of models, styles and features. Simple point-and-shoots, manual units, and technological marvels with multiple program modes, macro zoom lenses, and autofocusing systems *all* could be generated using this format as a platform. However, since only one specific model can be developed in this paper, it seems logical to concentrate on a basic, general purpose unit. More complex varieties can be left for future speculation.

The new unit is initially intended to fit a niche similar to the one automatic underwater point-and-shoot cameras now inhabit. To possess greater usefullness for the diver, the new model will operate at a greater maximum depth and will respond to a wider range of optical conditions. The unit is neither trying to compete with nor to replace underwater rangerfinders, SLRs in housings, or underwater autofocus SLRs. It is intended to broaden the diver's options. It should appeal to both amateur and professional divers that are interested in capturing images but do not have the time, inclination or resources to absorb all the subtle techniques and nuances of underwater photography.

Both the aesthetic and technical elements are equally significant in this design. The design must be functional. However, the importance of appearance for this new camera should not be underestimated. Because it will introduce people to the aquatic format, it is essential that the external appearance of the model reflect the inherent logic, simplicity and harmony of integrating a camera and a dive mask. The new unit must seem *natural*, not contrived. The new unit must not look like an oversized dive mask or camera glued onto a pair of glasses. An awkward design, that looks as if its members do not belong together, would close people's minds to the format before its technological benefits could be understood.

The design will be more than a camera and more than a dive mask. This union leads to a hybrid that is dissimilar from its 'parents', even though it functions as both. The integrated format is far more than the sum of its parts; it is a synergistic union.

Since this design is intended to represent a new direction in underwater photography, the new unit must offer ample room for additional growth. It must spark the imagination. A successful design should be inviting; both technical additions to and aesthetic variations on the basic form of the new unit must be anticipated and welcomed. The form must be complete in itself, but not be so 'refined' that it impedes future developments.

The successfulness of this design will be determined by how well it performs as a dive mask and a camera and by its ability to convince the divers whose photographic needs have not yet been met that they will gain substantially in overall performance, convenience and safety.

Aesthetic Goals

Combining a dive mask with a camera poses serious aesthetic challenges. Both are very well known and highly evolved forms. Their shapes are extremely different, and opposed to a degree. Cameras are visibly dense, dark, and technologically advanced little black boxes; dive masks, although physically larger, are spacious and airy—they appear light, and are relatively simple, having no moving parts. The new design must strike a harmonious balance between its parts to bridge this gap. It must be simple and elegant, like its "predecessors". Simply mounting a camera on top of a dive mask could result in an extremely awkward design (Figure 3.0). The direct addition of these well defined objects would yield a very complex and confused result.

It will automatically be *distinctive* since it is strange and new, but slightly familiar.

The reason that the new design should be aesthetically unpretentious is that it is intended to be adaptable. An intricate and stylized design might allow for little variation in color scheme, graphic treatment, and other detailing without losing the sense of identity and relatedness between different models.

The new unit must be simple and elegant, harmonious and understandable but slightly mysterious. Because of the context in which it will be used, it must look and feel appropriate in relation to the diver's face, the other paraphernalia of diving and the marine environment.

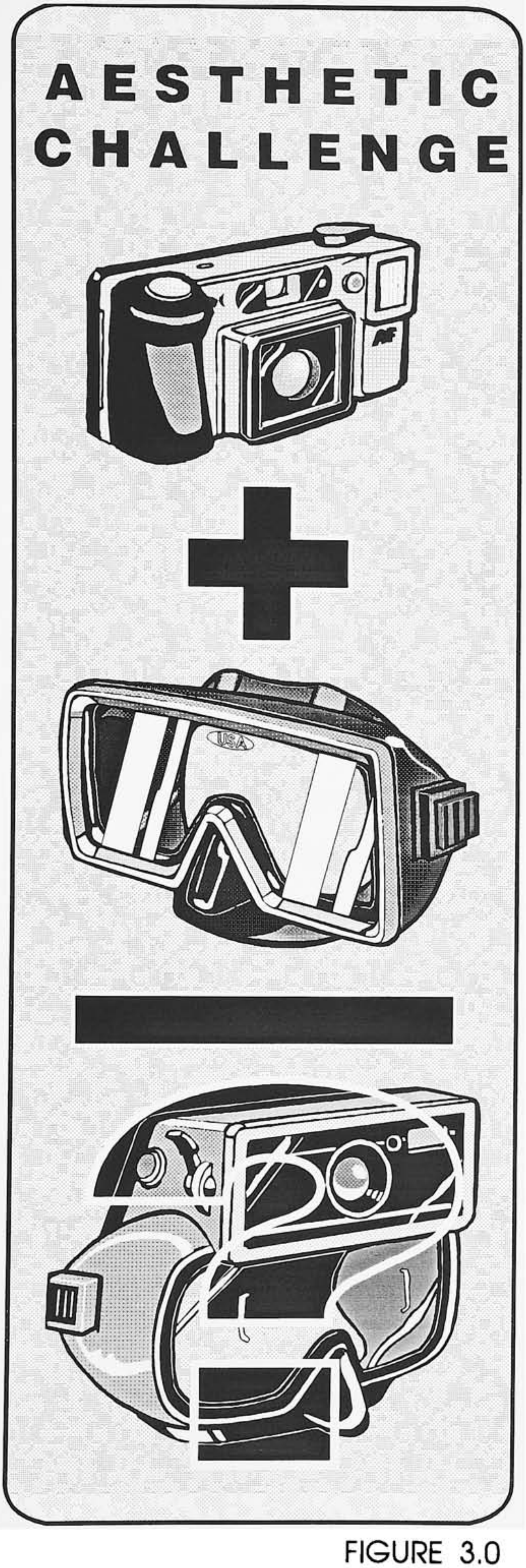


FIGURE 3.0

Technological Considerations

Because the working space and size of the unit are both highly constrained, the technical requirements of the camera and the configuration of components must be determined before choosing specific aesthetic details; they will directly impact the shape of the unit.

Figure 3.1 shows the basic size and shape of a typical compact camera and dive mask that are to be joined to produce a functional model. Figure 3.2 lists the major components that will be rearranged to form the integrated unit.

The functional requirements of the integrated design are determined by its dual roles as dive mask and camera. As a mask, the unit must protect the diver's eyes from the water. Conventional dive masks do this by using a flexible skirt to maintain a watertight seal around the front of the mask at the glass port's edges and at the back where the skirt touches to the diver's face. The skirt also acts as a "noseplug" by using the pressure of the surrounding water to pinch shut the diver's nose. Dive masks must be easily attached and removed in both air and water. The integrated unit must deliver a field of view comparable to regular dive masks. Since there is nothing about integrating the camera unit into a dive mask that interferes with these functions and demands, there is no reason why the new unit should perform them any differently.

The requirements of the camera unit are more intricate. The camera module to be incorporated into the mask housing must be roughly equivalent to a typical 35 mm point-and-shoot camera. The major difference between the two will be the

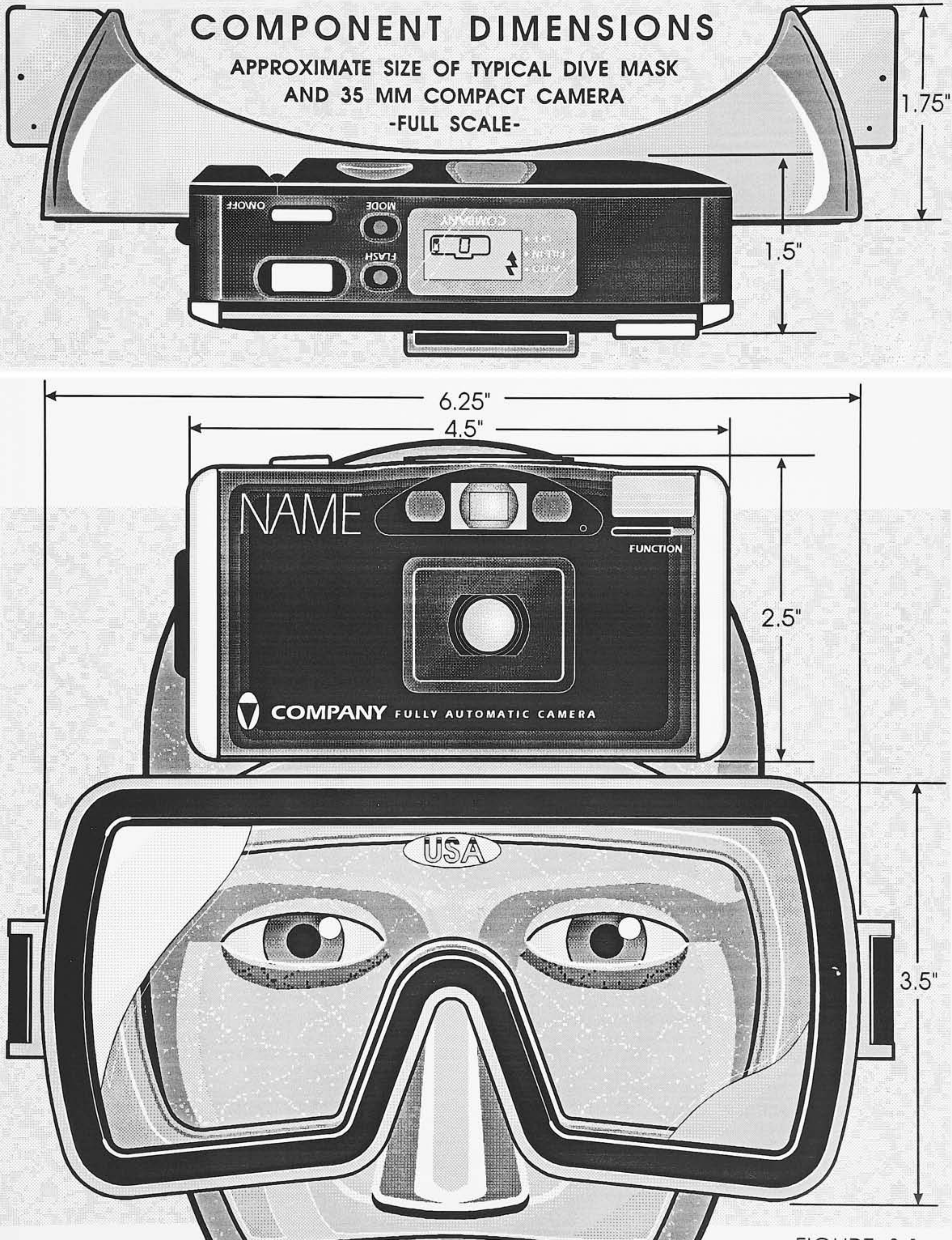

COMPONENT DIMENSIONS
APPROXIMATE SIZE OF TYPICAL DIVE MASK
AND 35 MM COMPACT CAMERA
-FULL SCALE-
1.75"
1.5"
6.25"
4.5"
2.5"
3.5"
NAME
FUNCTION
COMPANY FULLY AUTOMATIC CAMERA
USA

FIGURE 3.1

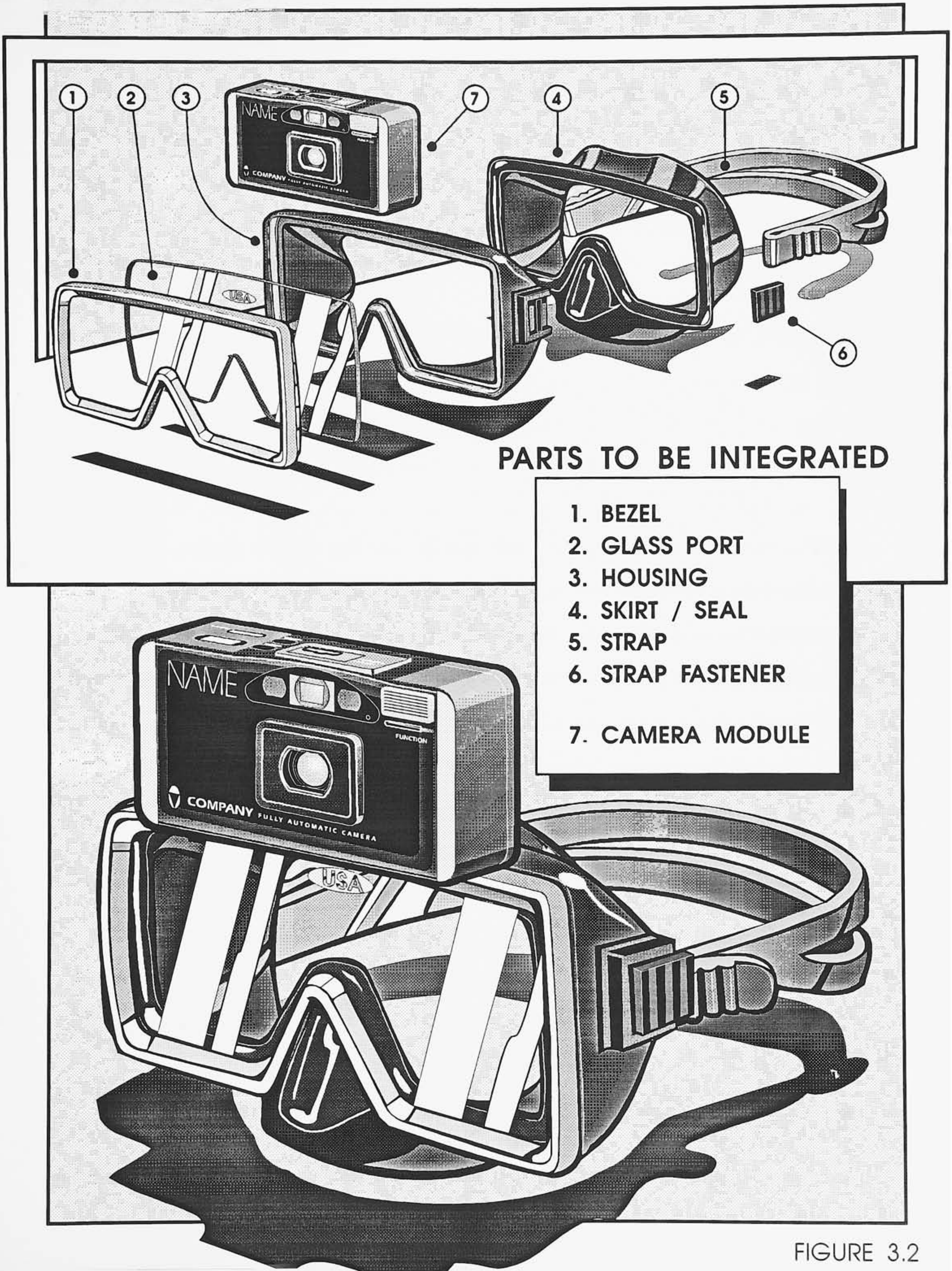

1
2
3
7
4
5
6
NAME
COMPANY
USA
PARTS TO BE INTEGRATED
1. BEZEL
2. GLASS PORT
3. HOUSING
4. SKIRT / SEAL
5. STRAP
6. STRAP FASTENER
7. CAMERA MODULE
NAME
FUNCTION
COMPANY FULLY AUTOMATIC CAMERA
USA

FIGURE 3.2

substitution of the mask/port for the conventional viewfinder. All the other optical and mechanical elements will be present because without them, the module could not function. However, these elements must be appropriately chosen to function well in the aqueous environment.

Of the camera module's technical considerations, film size, film transport, and focal length of the lens will substantially effect the size and appearance of the unit, since they will approximately establish the dimensions of the camera module (height, width and depth, respectively).

The camera module will use 35 mm film. It yields adequate detail without excessive graininess, and has easy access to processing and is by far the most common type of film. Larger film types would make the unit too big to wear comfortably on the head. Smaller film types would reduce the size of the camera unit, easing the task of integration, but, considering the other factors affecting image quality underwater, the increased graininess and loss of resolution on the film, would more than offset any substantial improvement in size. 35 mm film provides an ideal compromise between image resolution, size of the unit, and convenience.

The 35 mm film transport systems will be automated. Its features include motorized advance and rewind, as well as DX coding for automatically reading the film speed from the film magazine. All of these features reduce the demands made on the diver both before entering the water and while submerged. An automated transport system eliminates the need for advance/rewind knobs protruding from the housing. This simplifies both the appearance and the operation of the unit.

The optical system of the camera module will consist of a high-quality glass wide-angle fixed-focus lens. The focal length of the lens will be chosen so that the image recorded will closely correspond to the underwater field of view of the diver, as seen through the front port of the mask.

For a basic underwater camera model, the fixed-focus method of focusing offers many advantages. Since visibility underwater is naturally limited by the optical conditions of the water (to 90 ft. maximum), using such a fixed-focus lens will produce a suitable depth of field to yield a wide range of sharp focus. It also avoids having to include either circuitry and sensors for an autofocus system or control devices for a manual focusing system. Fixed-focus is simply the easiest and most appropriate choice for the initial model. The images it records will be sharper than if taken by a conventional underwater point-and-shoot camera in a fixed-focus mode because the focal length of the lens will be shorter, and the optical quality of the glass will be higher. It will also decrease the number of the module's moving parts reducing size, weight and complexity.

The exposure system—consisting of aperture, shutter, and metering device—will be equivalent to those of a modern compact camera to minimize the size of the camera module. The metering system should be as similar to a spot meter as possible. The ideal location for the metering device is Through The Lens (TTL), to allow for direct reading of the light that will form the image. However, if TTL metering is not feasible because of the cost or size of the sensor arrays, a single sensor should be mounted close to the lens and have a very small area of sensitivity, only reading the center most section of the field of view. This will avoid the problems that standard metering systems encounter (as described in the previous chapter). This will ensure that the subject is exposed properly and reduce the overpowering effect of the largely murky background.

The meter readings will be sent to an onboard microcomputer that will control the camera's systems. With the proper underwater exposure program the photos recorded should be very accurately exposed.

The camera module is regulated by computer, and the shutter button is the only control the diver must operate. The shutter button should be located somewhere on the unit that is easily reachable. An alternate way of triggering the shutter is also desirable, since this would allow for a range of accessories to be developed. For example, a hand-held flash unit that could trip the shutter would be a great convienience for the diver. Since the module is fully automatic, a control panel is not necessary.

All of these decisions minimize both distractions and the complexity of the photographic tasks a diver must perform when they see an image that they want to record.

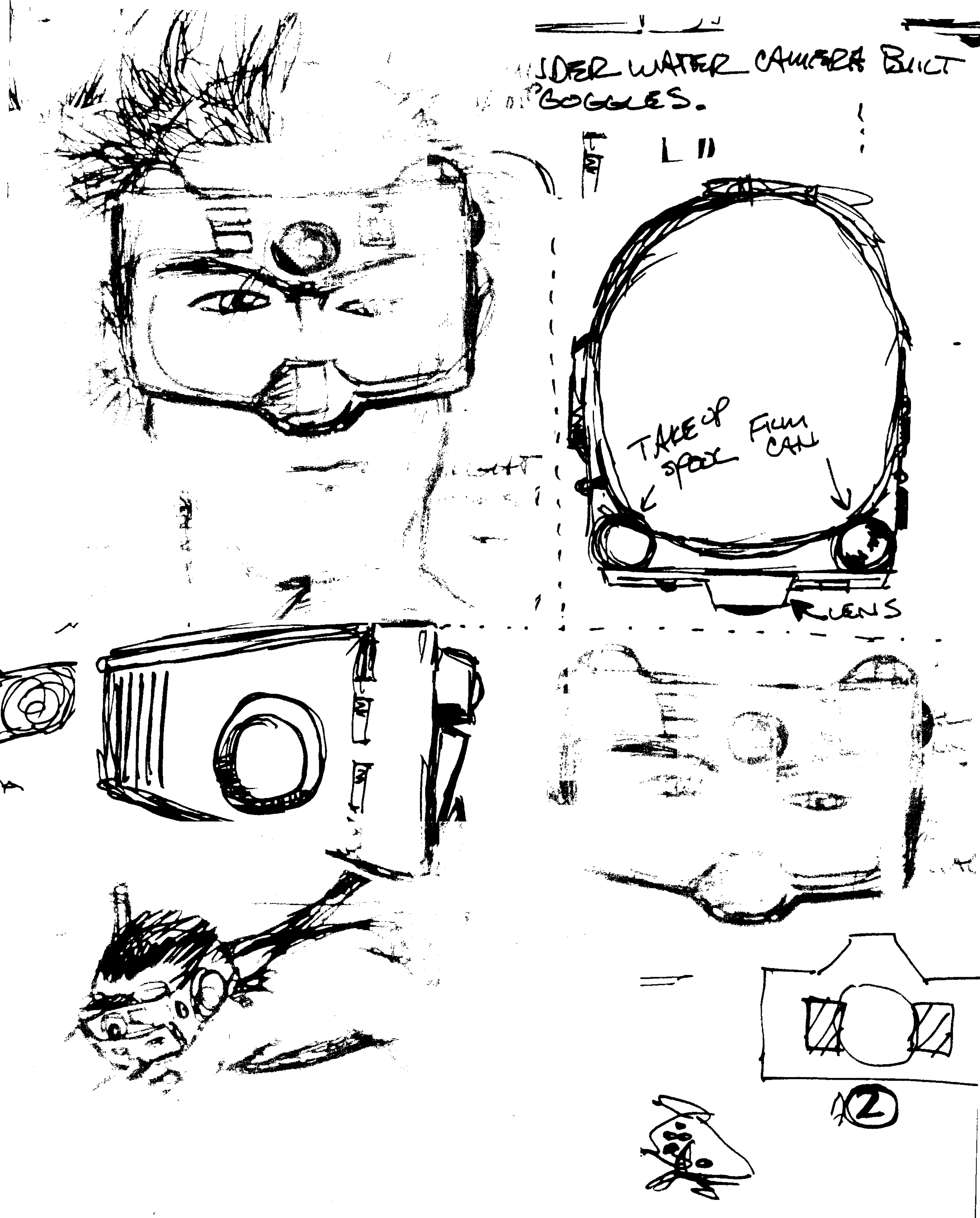


FIGURE 3.3

Configuration and Form

Several essential technical questions need to be addressed before trying to determine the integrated camera unit's form. How should the components of the camera module and the dive mask be arranged to function best in the underwater environment? The same functions can be achieved by several different configurations. Even though they are functionally equivalent, each arrangement leads the form to different aesthetic directions.

The most significant of these considerations is the location of the module on the mask and the orientation of the film plane within the camera module. This placement will substantially affect the appearance of the unit. Even though the initial concept sketches (FIGURE 3.3) showed a film plane traveling across the temples it would be shortsighted not to examine alternate configurations. Several variations are possible, and each one possesses unique advantages and disadvantages.

There are only three possible locations for the camera module to be attached to the mask. It could be located on top of the mask across the temples, on the side, or on the bottom. The last possibility is extremely impractical, since it interferes with both the diver's field of vision and their ability to breathe, by partially blocking the mouth.

Locating the camera at the side of the head, as in Figure 3.4_1, allows the lens to be in line with the eyes. In this configuration, when the eye farthest from the lens is closed, the open eye sees fair approximation of the view of the lens. This placement would be off-balanced unless an additional element, perhaps a flash unit, was used as

CAMERA MODULE CONFIGURATIONS

THE SIZE AND ARRANGEMENT OF THE COMPONENTS MAKING UP THE CAMERA MODULE GREATLY AFFECT THE FORM OF THE RESULTING UNIT. DIFFERENT CONFIGURATIONS CAN PERFORM THE SAME FUNCTIONS, SO EACH SHOULD BE EXAMINED FOR ADVANTAGES AND DISADVANTAGES.

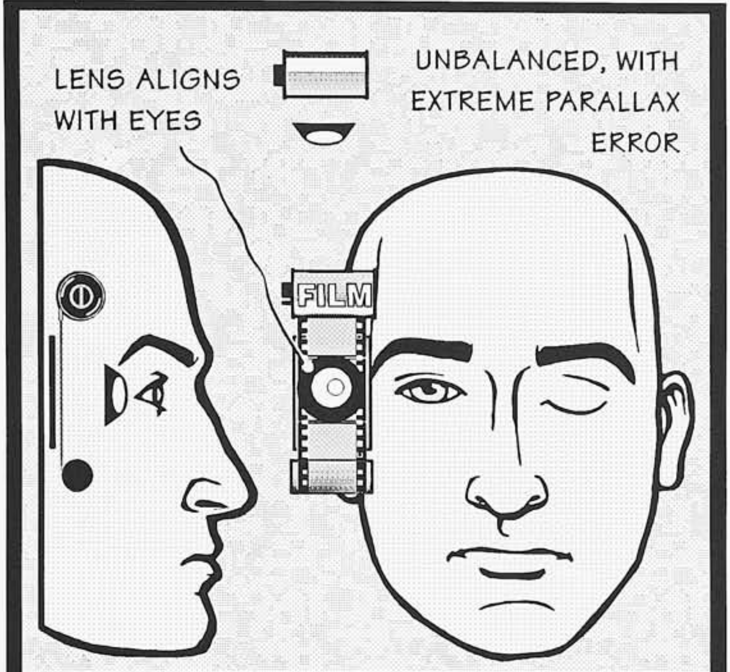


FIGURE 3.4_1 BESIDE HEAD

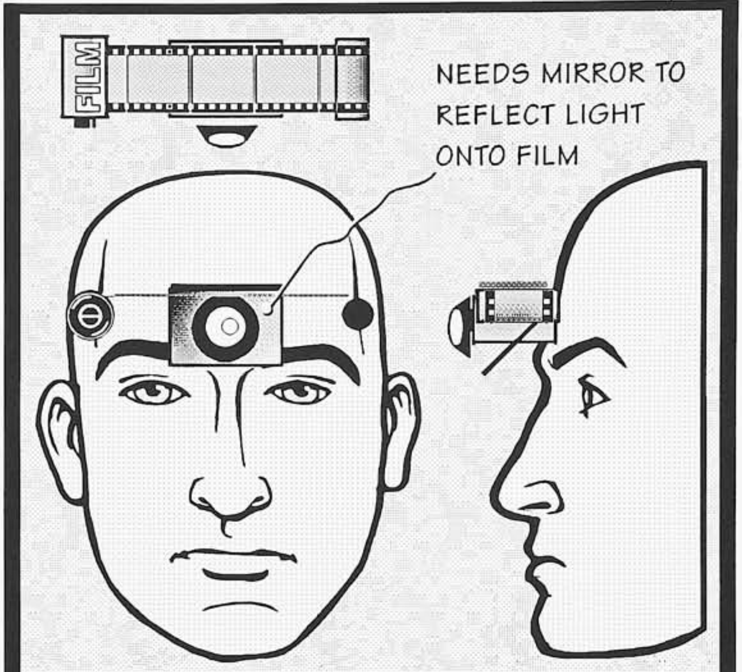


FIGURE 3.4_2 PERPENDICULAR

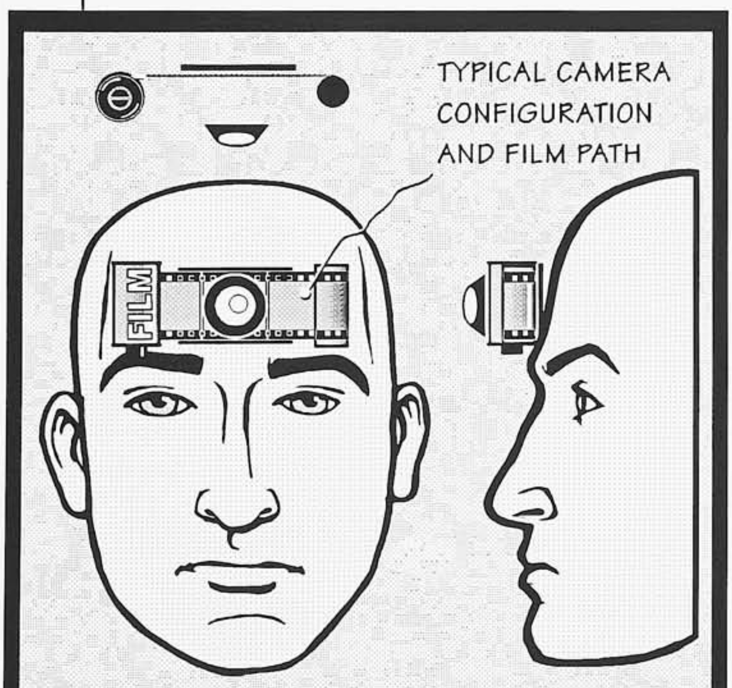


FIGURE 3.4_3 NORMAL 35 MM

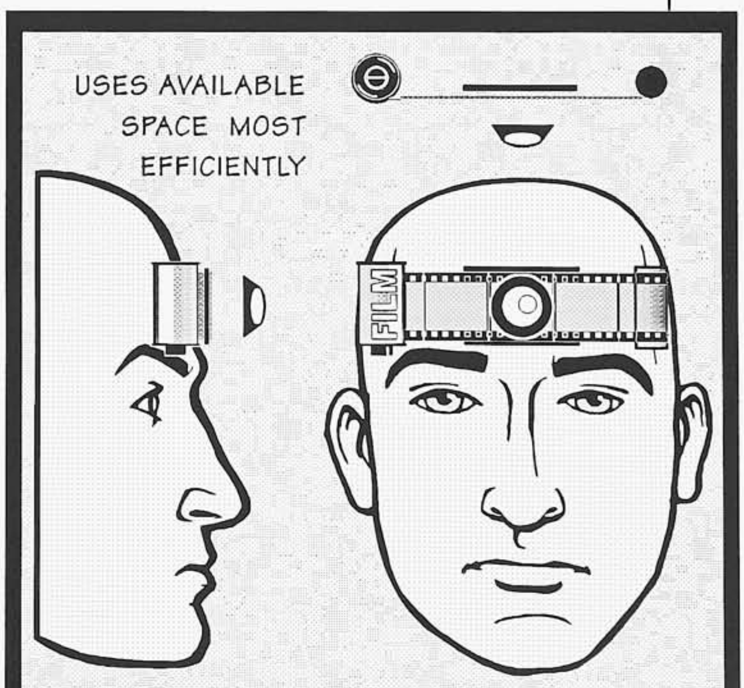


FIGURE 3.4_4 WRAP AROUND

FIGURE 3.4

a counterbalance. The resulting unit would be wide and flat, with protrusions on each side, like a hammerhead shark. The major disadvantage of this configuration is that closing one eye, the diver would still be limited to a myopic view. The images recorded would appear shifted to the side from the diver's point of view. This orientation is more complicated, presents fewer advantages and is less safe than the initial concept.

The only other feasible location for mounting the camera module is across the temples. However, there are several variations to this configuration. The module could be located across the forehead with the focal plane perpendicular to the port, as in Figure 3.4_2. This makes use of the receding slope of the forehead to position the lens extremely close to the eyes, for a very compact design. However, a mirror is required to bounce the light entering the lens onto the focal plane, which is actually pointing down.

The focal plane could be located across the temples parallel to the port. With this location, at least two other variations are possible. The first, Figure 3.4_3, shows a module with the same film transport system as a standard camera placed across the temples. Here the bottom rear edge of the camera rests at the front of the diver's brow. This module would be substantially narrower than the mask section, and the front of the module would protrude past the port. The advantage of this configuration is that the mechanisms of any point-and-shoot camera could easily be mounted into this position, so that a manufacturer would only have to use different housings to make both land and underwater cameras using the same mechanisms.

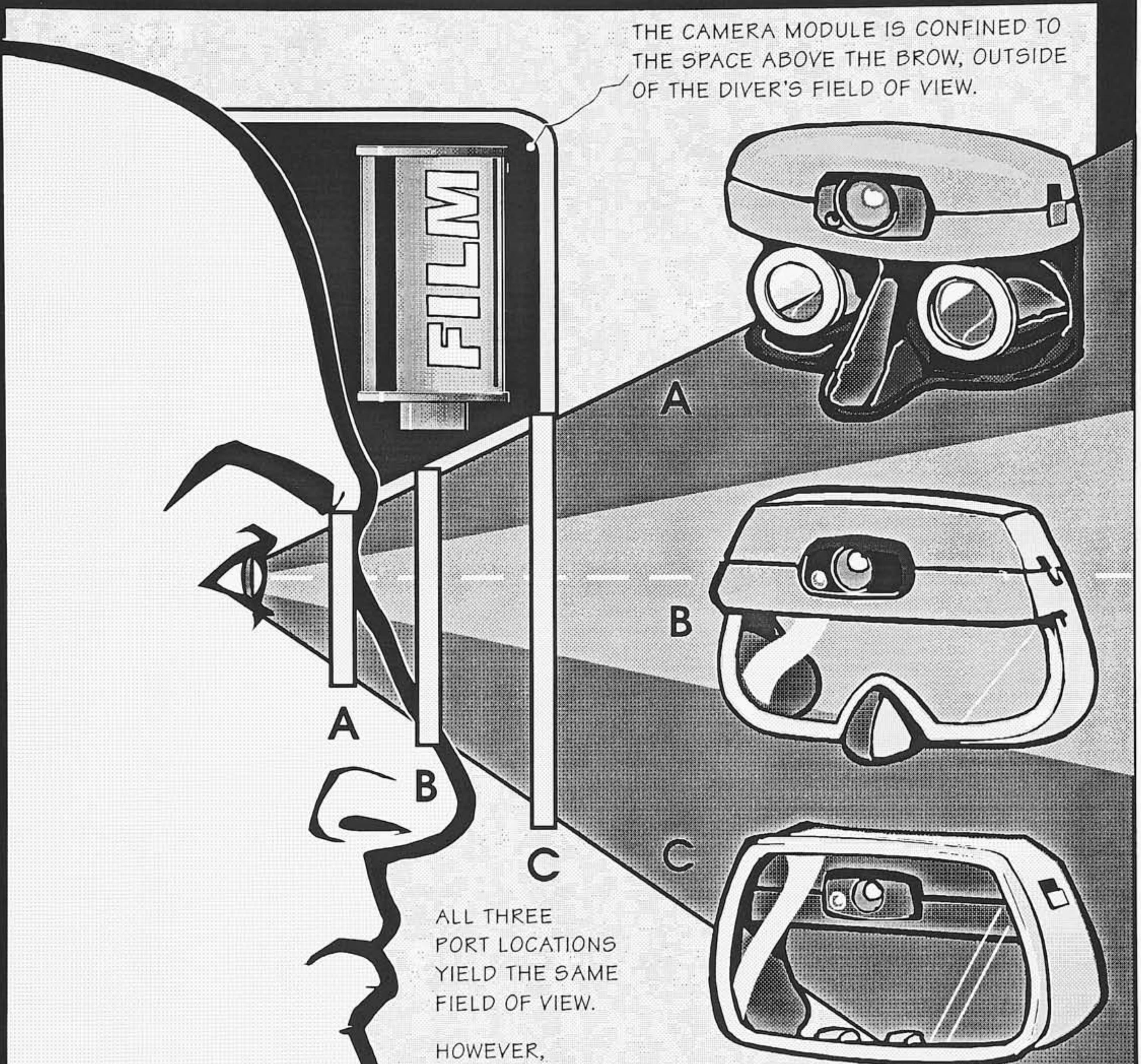
The placement of the take-up spool and the film canister could be stretched apart from their normal flat configuration so the path of the film wraps around the forehead at the temples; rearranging these components produces a wider module that does not protrude as far past the plane of the port. This module makes the most efficient use of the shape of the head (FIGURE 3.4_4).

Because they are faithful to the initial concept and pose the least problems adapting the conventional technology to this application, the last two modules were vigorously explored.

Another question that dramatically affects the overall appearance of the unit is the distance from the eyes to the glass port on the front of the dive mask. As Figure 3.5 illustrates, the space available for the camera mechanism is determined by the depth of the module, and its placement on the forehead. The module should not be located so low that it blocks the top part of the diver's field of view. The plane of the port can be located anywhere from extremely close to the eye (a), through an intermediary position (b), to past the end of the camera module (c).

As the port moves from close to the eyes to more remote locations, the character of the mask drastically changes. When the plane of the port is close, the resulting mask is composed of separate and very distinct shapes; the mask becomes a pair of goggles, and the unit becomes a bulbous collection of masses (FIGURE 3.5 A).

PORT LOCATION AND HOUSING FORM



THE LOCATION OF THE MASK'S PORT DETERMINES THE VOLUME OF AIR IN THE MASK AND GREATLY AFFECTS BOTH THE PROFILE AND THE FINAL SHAPE OF THE UNIT.

FIGURE 3.5

At intermediary positions, the unit has a jagged profile. As seen from the side, the front of the camera module is thrust past the plane of the port. This produces a strong division between the mass of the mask and the camera. Also, the port must accommodate the protrusion of the nose. The camera module has to be carefully located to avoid blocking the diver's field of view (FIGURE 3.5 B).

At its most remote location, the entire camera module can be encased behind the plane of the port. With the module "swallowed", the unit appears to be an oversized dive mask with an extra device inside. Although maximum unity is obtained with this situation, since both module and mask are enclosed within the rim of the housing, the camera appears to be a subset of the mask. However, the whole unit has a very large volume and a very bulky, simple shape (FIGURE 3.5 C).

The amount of air behind the port is a significant factor in determining the character of the mask. The farther away from the face the port is located, the greater the volume of air the mask holds; underwater, this air must be expelled (purged) from the mask when it is reattached. The larger the volume of air in the mask, the more difficult it becomes to purge. Large volumes also require more material and increases the visual size of the mask.

Diver's Field of View and the Image

For the camera module to successfully capture the full range of the diver's field of view, the lens should be located directly above the midpoint of eyes, and be as close to the diver's line of sight as possible. This positioning is crucial since, the discrepancy between the image is recorded on the film and what the diver actually sees will be directly related to the location of the lens above the eyes. This discrepancy is called *parallax error* (Figure 3.6).

The higher the lens is positioned above the eyes, the greater the parallax error. For objects located far from the diver, the discrepancy will be slight, but the closer the diver is to the subject to be photographed, the more noticable this error becomes.

For the port to function properly as the viewfinder, it must unambiguously block out an area that closely approximates the image that will be recorded on the film. For this reason a single port or split port seem to be the most sensible choices. Additional ports on the top or the side of the mask would expand the peripheral vision, but would also increase the effort required to determine what part of the view will be recorded on film. The diver should not have to concentrate on identifying the specific location of the fringes of their field of view. A simple port configuration will make composing and capturing the image nearly effortless. If it can be seen, it will be recorded.

Even if the diver is not looking straight ahead, the mask still functions adequately as a viewfinder, as illustrated in Figure 3.7.

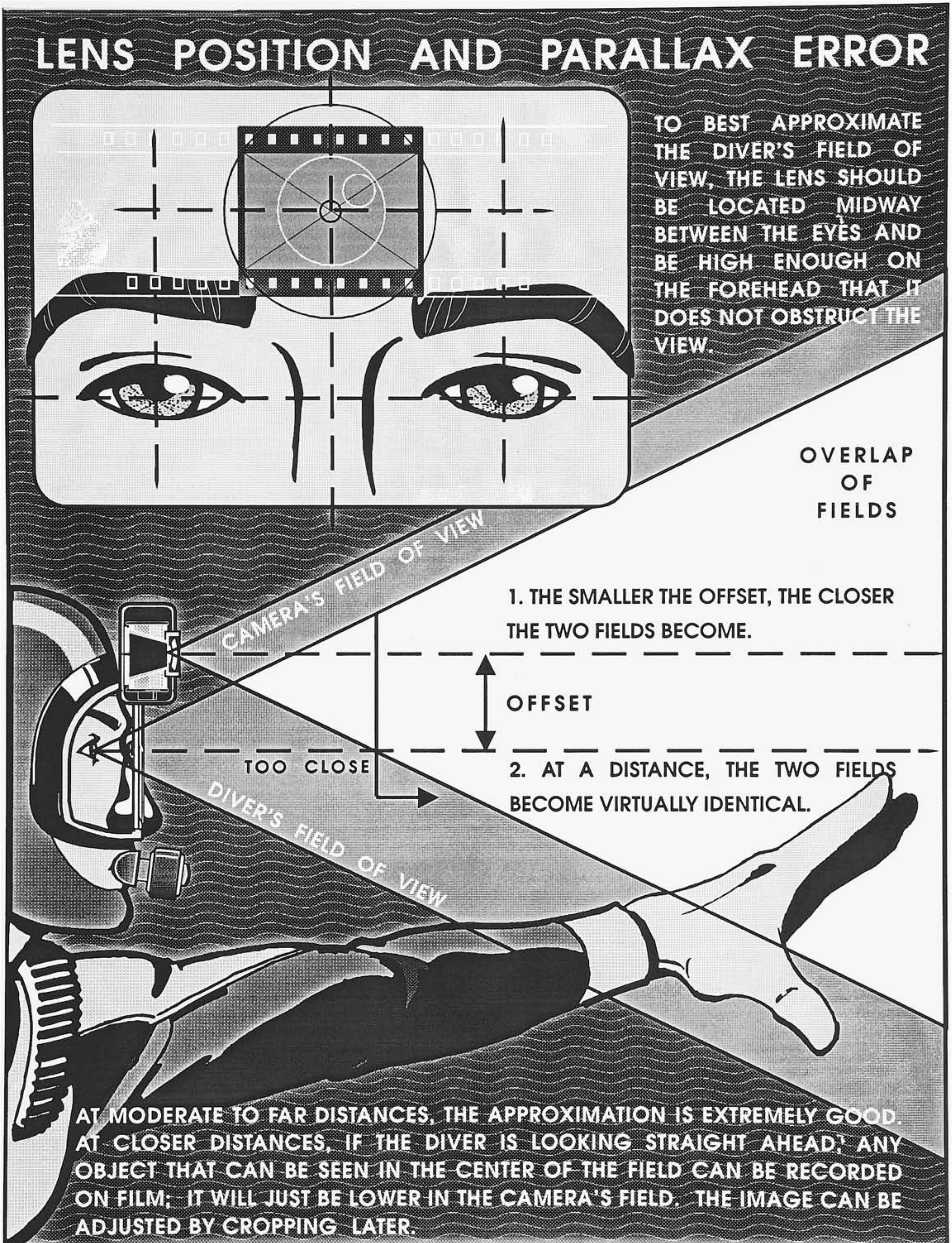

LENS POSITION AND PARALLAX ERROR
TO BEST APPROXIMATE THE DIVER'S FIELD OF VIEW, THE LENS SHOULD BE LOCATED MIDWAY BETWEEN THE EYES AND BE HIGH ENOUGH ON THE FOREHEAD THAT IT DOES NOT OBSTRUCT THE VIEW.
OVERLAP OF FIELDS
CAMERA'S FIELD OF VIEW
1. THE SMALLER THE OFFSET, THE CLOSER THE TWO FIELDS BECOME.
OFFSET
TOO CLOSE
2. AT A DISTANCE, THE TWO FIELDS BECOME VIRTUALLY IDENTICAL.
DIVER'S FIELD OF VIEW
AT MODERATE TO FAR DISTANCES, THE APPROXIMATION IS EXTREMELY GOOD. AT CLOSER DISTANCES, IF THE DIVER IS LOOKING STRAIGHT AHEAD, ANY OBJECT THAT CAN BE SEEN IN THE CENTER OF THE FIELD CAN BE RECORDED ON FILM; IT WILL JUST BE LOWER IN THE CAMERA'S FIELD. THE IMAGE CAN BE ADJUSTED BY CROPPING LATER.

FIGURE 3.6

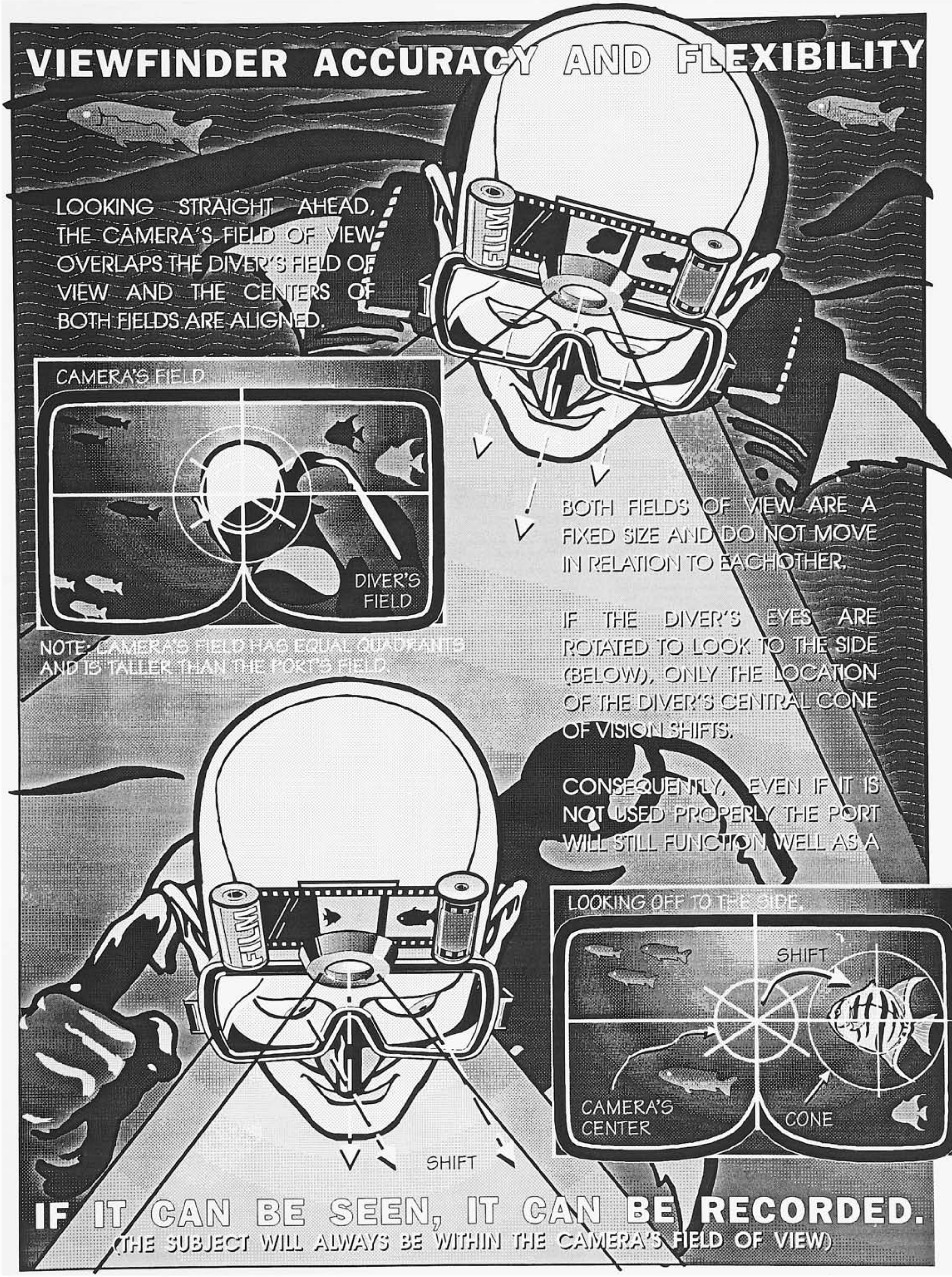

VIEWFINDER ACCURACY AND FLEXIBILITY
LOOKING STRAIGHT AHEAD, THE CAMERA'S FIELD OF VIEW OVERLAPS THE DIVER'S FIELD OF VIEW AND THE CENTERS OF BOTH FIELDS ARE ALIGNED.
FILM
CAMERA'S FIELD
DIVER'S FIELD
NOTE: CAMERA'S FIELD HAS EQUAL QUADRANTS AND IS TALLER THAN THE PORT'S FIELD.
BOTH FIELDS OF VIEW ARE A FIXED SIZE AND DO NOT MOVE IN RELATION TO EACHOTHER.
IF THE DIVER'S EYES ARE ROTATED TO LOOK TO THE SIDE (BELOW), ONLY THE LOCATION OF THE DIVER'S CENTRAL CONE OF VISION SHIFTS.
CONSEQUENTLY, EVEN IF IT IS NOT USED PROPERLY THE PORT WILL STILL FUNCTION WELL AS A
LOOKING OFF TO THE SIDE.
SHIFT
CAMERA'S CENTER
CONE
FILM
SHIFT
IF IT CAN BE SEEN, IT CAN BE RECORDED.
(THE SUBJECT WILL ALWAYS BE WITHIN THE CAMERA'S FIELD OF VIEW)

FIGURE 3.7

Configuration, lens location, port location, and the number of ports are all interrelated, and all profoundly affect the form of the final unit.

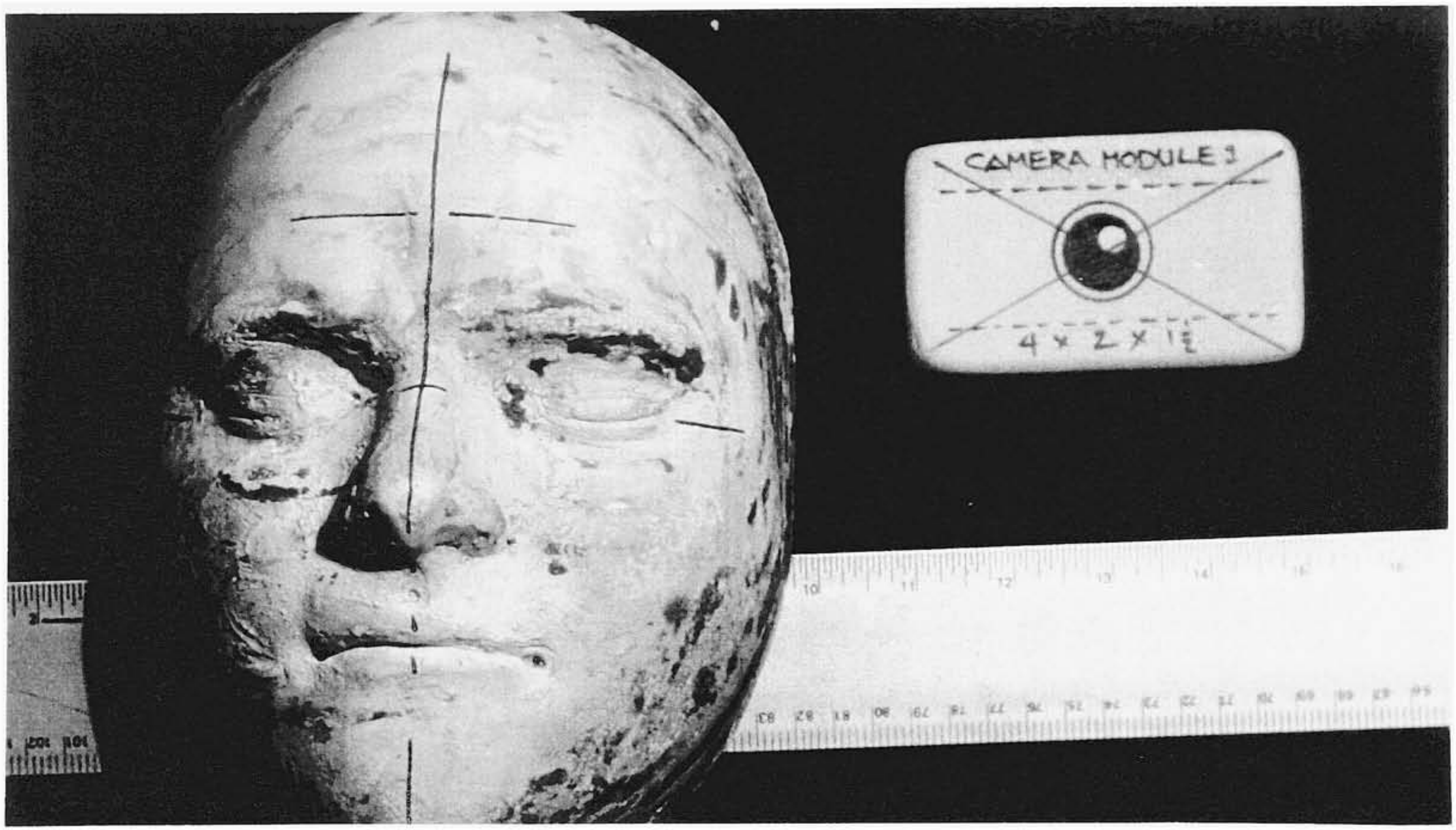
Which options are superior was not immediately apparent. The initial phases of the design process evaluated a variety of models, until the ones with the most substantial benefits for the current application made themselves known. This process eliminated the least advantageous alternatives from consideration and let the others gradually develop.

Generating the Form

Initially, thumbnail drawings of a camera integrated onto a dive mask captured the basic concept. Although adequate to record the first creative impulses, these sketches could not establish the feasibility of the concept. Three-dimensional models were necessary to ensure that the design would be a realistic and manageable size, and that it would fit the diver's head.

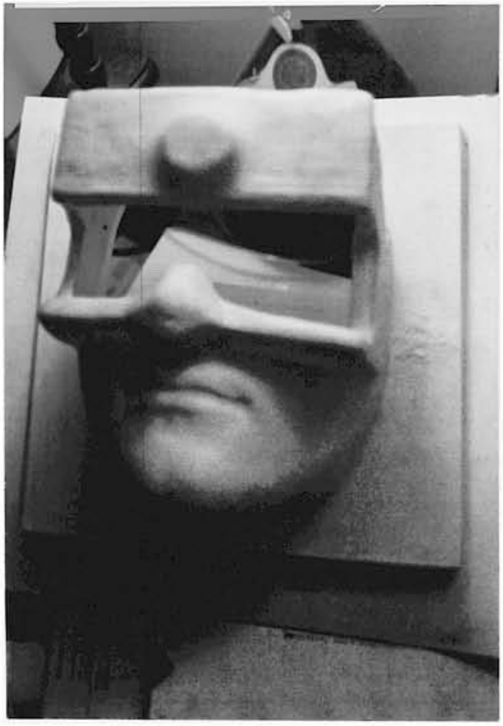
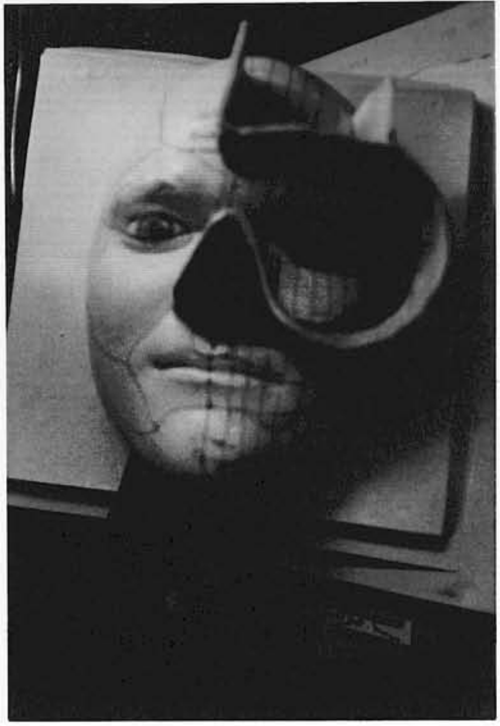
Before doing renderings or sketch models, it was necessary to develop approximate physical dimensions for the mask housing and the camera module. The housing was to be roughly the same size as a typical dive mask. The camera module could be somewhat smaller than a conventional compact camera, since it lacks a built-in viewfinder and the electronic components for auto-focusing. Therefore, the dimensions 4" x 2"x1½" were chosen.

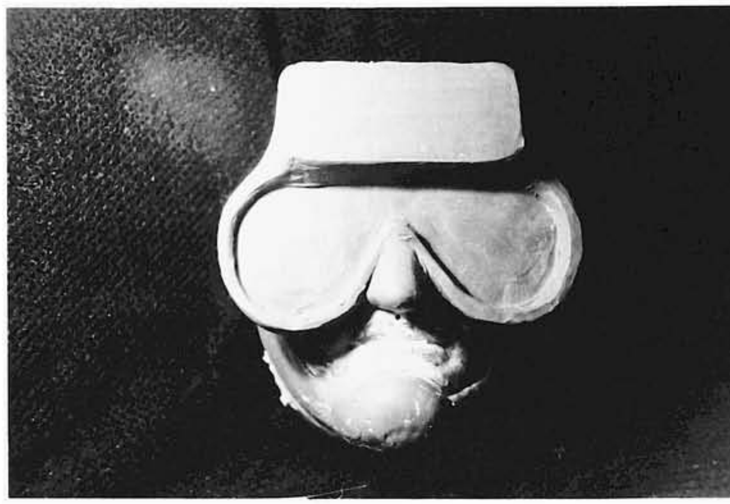
After choosing these dimensions, a number of plasticine 3D sketch models were developed. A plaster cast of a wider-than-average human head served as a foundation for all of these models. Clay was applied around a block of foam representing the camera module. The mask housing was sculpted around this block and the cast head to generate a variety of forms.



Plaster head and camera module used for base of sketch models.

FIGURE 3.8

A variety of 3-dimensional sketch models.

Most are of Plasticine formed on a plaster head. The photo in the upper left corner shows the vacuum-formed feasability model.

FIGURE 3.8b

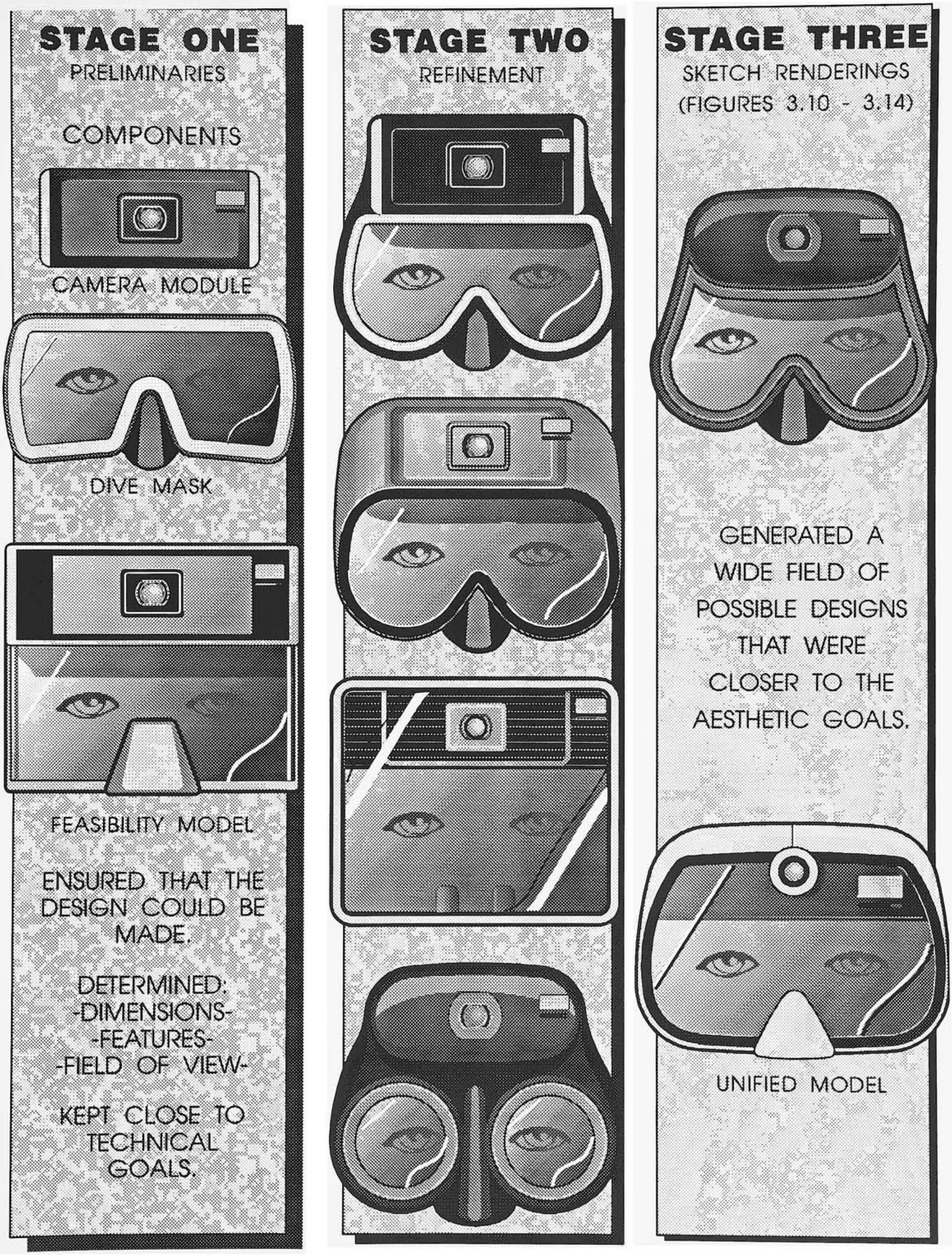

STAGE ONE
PRELIMINARIES
COMPONENTS
CAMERA MODULE
DIVE MASK
FEASIBILITY MODEL
ENSURED THAT THE DESIGN COULD BE MADE.
DETERMINED:
-DIMENSIONS-
-FEATURES-
-FIELD OF VIEW-
KEPT CLOSE TO TECHNICAL GOALS.
STAGE TWO
REFINEMENT
STAGE THREE
SKETCH RENDERINGS
(FIGURES 3.10 - 3.14)
GENERATED A WIDE FIELD OF POSSIBLE DESIGNS THAT WERE CLOSER TO THE AESTHETIC GOALS.
UNIFIED MODEL

FIGURE 3.9

Model Making

The first of these models firmly established the concept's feasibility. This model enclosed the volume necessary for a working camera in a housing that also provided the field of view of a dive mask. After vacuum forming and cutting out the port area a plastic version of the clay model allowed the field of view to be tested. This gave the design a permanent, realistic base of comparison.

The initial feasibility sketch model was shown to a variety of people for feedback and the unanimous response was that it looked much too "boxy". Since this model intended to establish basic dimensional requirements, and had to be vacuum formed easily, it had a very crude appearance. Although this model was simple, it looked primitive, old, and unrefined; even worse was that it looked out of place sitting on a person's face. The mask and camera were too distinct and unrelated, causing the model to look as if its component parts had been reluctantly joined.

The form clearly needed to be altered. The next step in the process was to systematically refine the form so that it conformed more closely to the aesthetic goals, as well as the technical qualifications. The design process now began to progress through both sketches and three-dimensional models simultaneously.

Second Stage

Next, several new forms that tried to eliminate the boxiness of the initial model were developed. All avoided the linearity of the previous model with its square, tight corners, and boxy appearance by applying curves to the models. This was intended to make the models better suited for the underwater environment, and tried to give these models a comfortable feel, as well as a better look. Each model tried to accomplish these objectives in different ways. This was intended to generate a wider range of ideas for further development.

Several new forms were modeled on plaster heads. These forms also possessed a marked distinction between the mask and the camera module. This strong division occurred because the modeling focused on trying to keep the size of the unit as small as possible. Unifying the elements required adding clay to the foam block representing the camera module and the mask/housing which greatly increased model's size. Despite these tight constraints, several variations with very different characters emerged.

Two of these clay models used curves to harmonize the components. In both, the mask was rounded off for a more curvilinear look and to make the mask connect to the camera module. The first (shown at the top of the middle column of Figure 3.9) used an 'S' curve for the connection. This looked much less awkward than the original model, but it was not very harmonious. The top and bottom were connected, but not related. The small volume of the mask was definitely a positive attribute, but the components were still not integrated.

Directly below in the middle column of Figure 3.9, the second model embraced the top and bottom with a single convex curve. This model was much more unified because both mask and module were enveloped by the curve. However, the unit appeared very large and bulky, since it had to incorporate both the width of the mask and the camera's height.

Since the front of the camera module protruded past the port on both of these models, their profiles were stepped and jagged, just like the initial model. The profiles made these units seem overly large, and placed the lens high above the diver's eye level—neither of which were desirable traits.

Two alternative variations were pursued on paper in this series, and both contributed significant new design elements. The first turned the mask into a pair of goggles connected to the separate mass of the camera on top. The second had a single large port that completely enclosed both elements, which led to a very unified model. Unfortunately, it was all "mask". These are shown in the bottom two designs in the middle column of Figure 3.9.

Overall, this second generation overcame the problems of the initial model, but still lacked the desired harmony and balance necessary to achieve proper integration.

Sketch Renderings

The third series of designs attempted to aggressively develop an unified, integrated form. Three-dimensional models were temporarily left behind to avoid the physical constraints of working around the foam cube, so that more variations could be quickly generated and compared, to zero in on the form best suited to the aesthetic goals.

A number of sketch renderings were used to find new directions and look at the unit as a whole, rather than a collection of discordant parts. More details were considered in determining these forms than on the sketch models. Since the final form was not to be unified primarily by its final details, the overall shape had to be unifying for a strong identity. This would allow the details to be altered from model to model while maintaining a sense of identity. These renderings varied from the previous approach of keeping the design close to reality. Although the renderings looked good on paper, some had proportions for the mask and camera module that could not possibly work in three-dimensions.

This series succeeded in creating a wide range of possible designs to choose from. The designs showed a great deal of variation. Some of them were sober and understated while others became quite whimsical. All the forms, with some alteration, could lead directly to viable final models. This shows quite clearly the aesthetic flexibility of the integrated format.

The strongest direction for the final form emerged in this group of renderings.

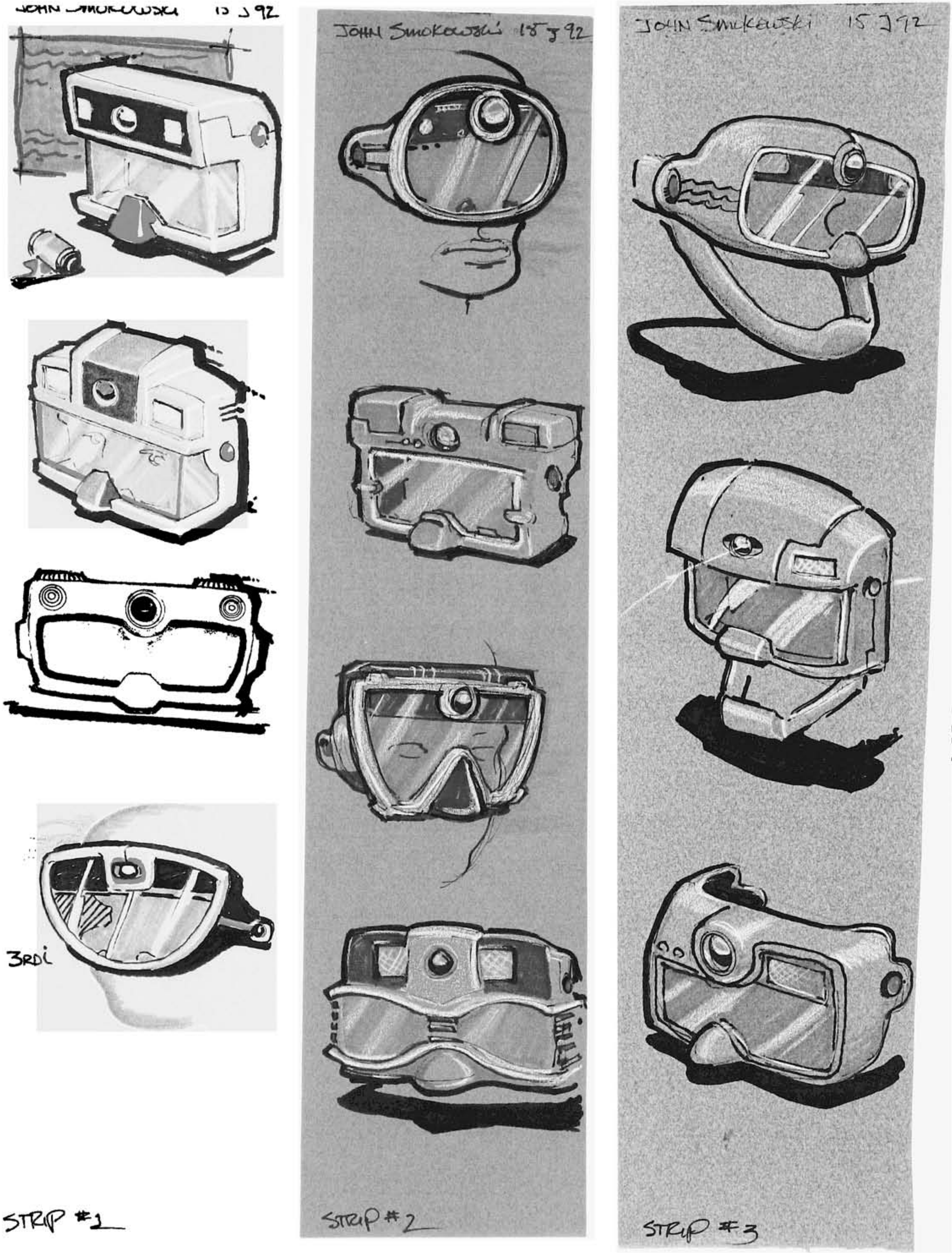

JOHN SMOKOWSKI 15 J 92
JOHN SMOKOWSKI 15 J 92
3RDi
STRIP #1
STRIP #2
STRIP #3

FIGURE 3.10

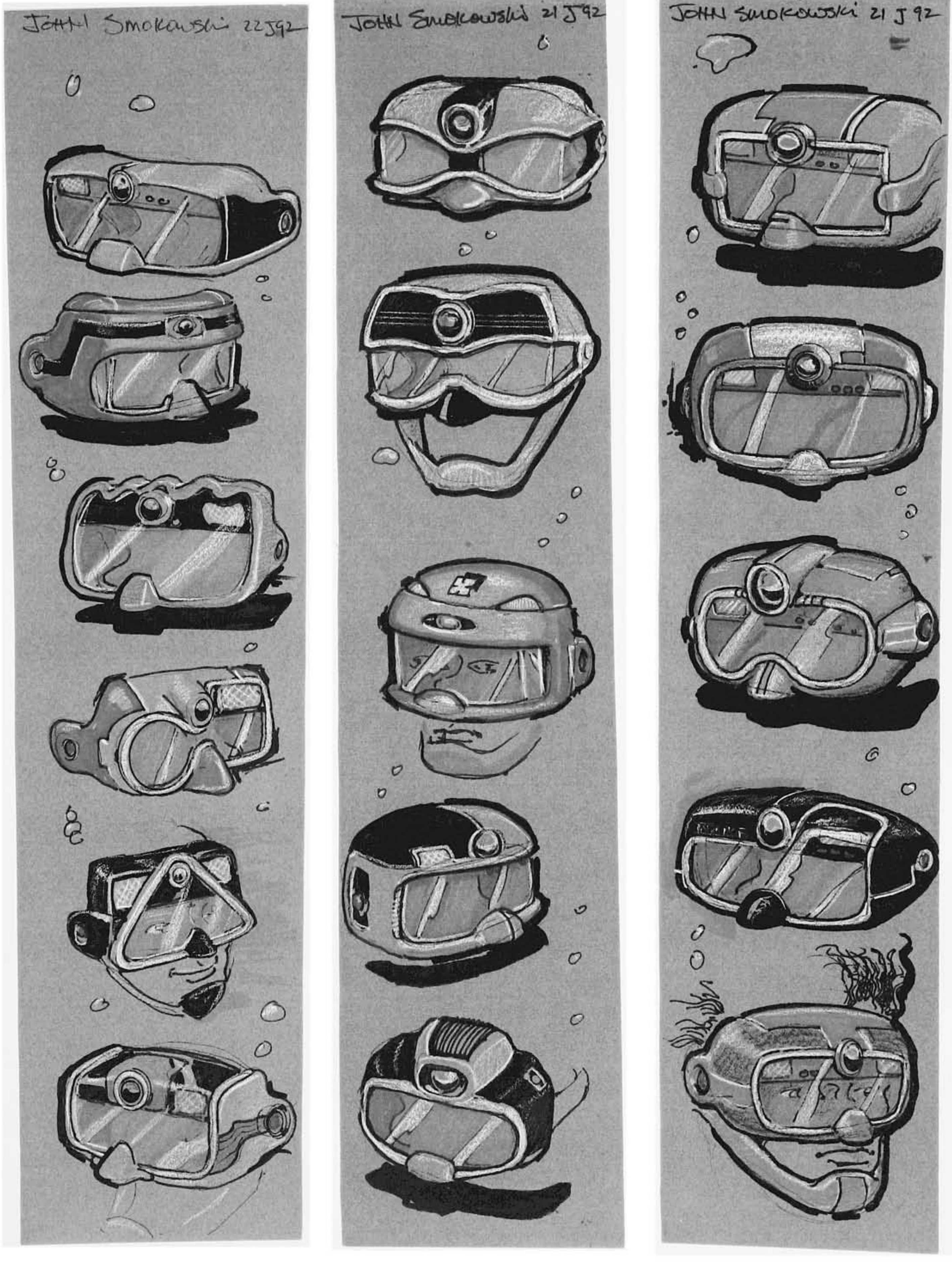

JOHN SMOKOWSKI 22J92
JOHN SMOKOWSKI 21J92
JOHN SMOKOWSKI 21 J 92

FIGURE 3.11

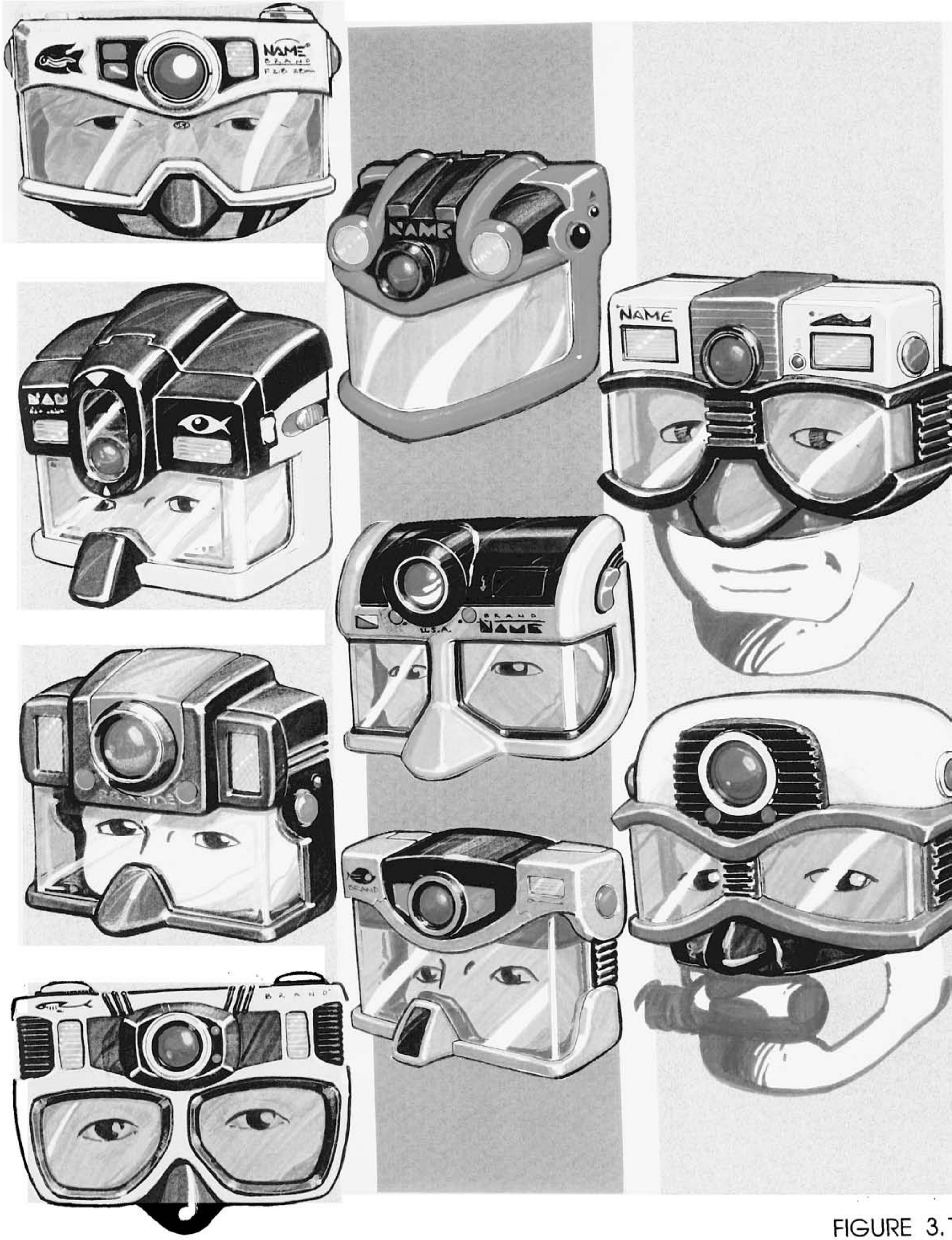


FIGURE 3.7

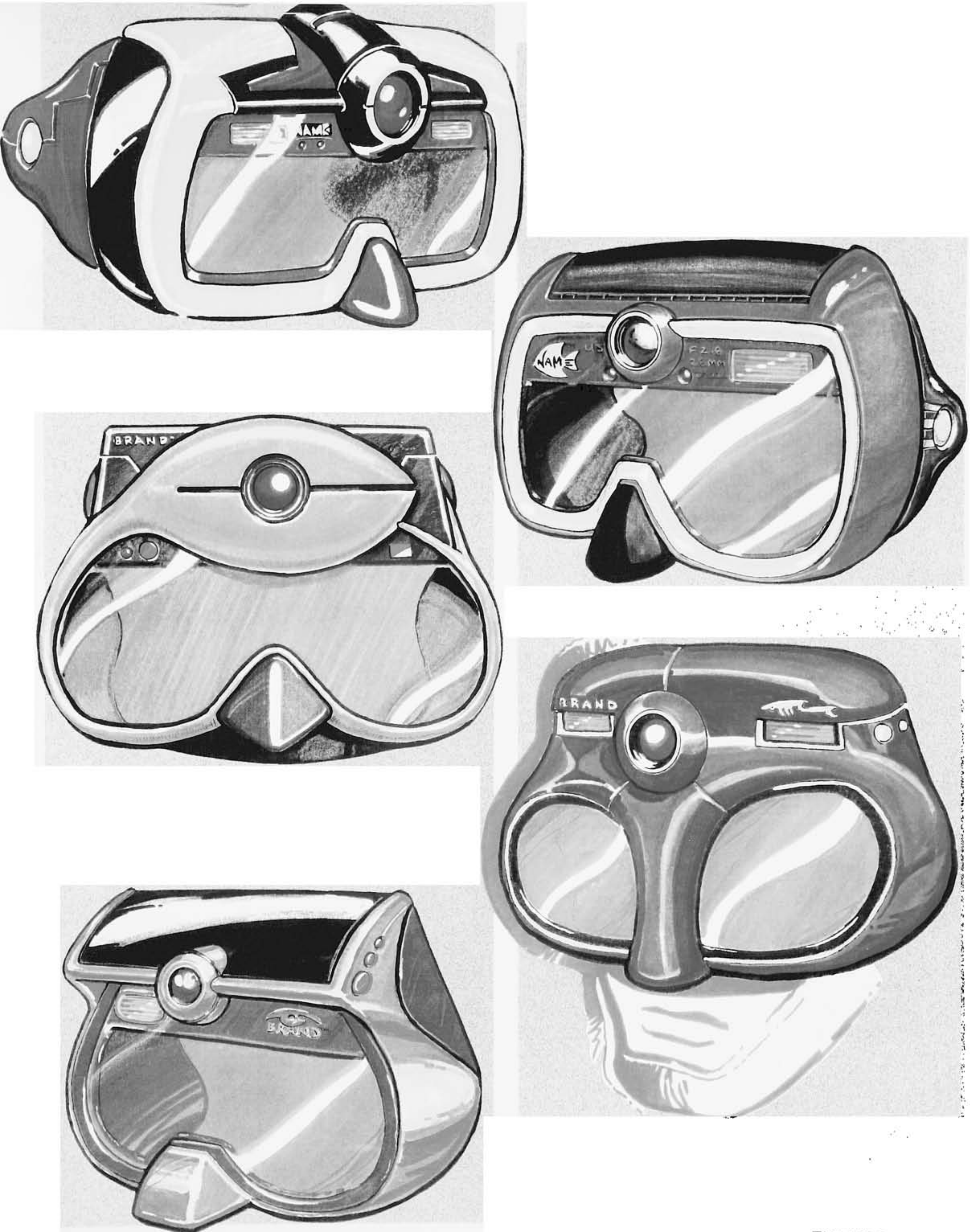


FIGURE 3.13

UNIFIED MODEL

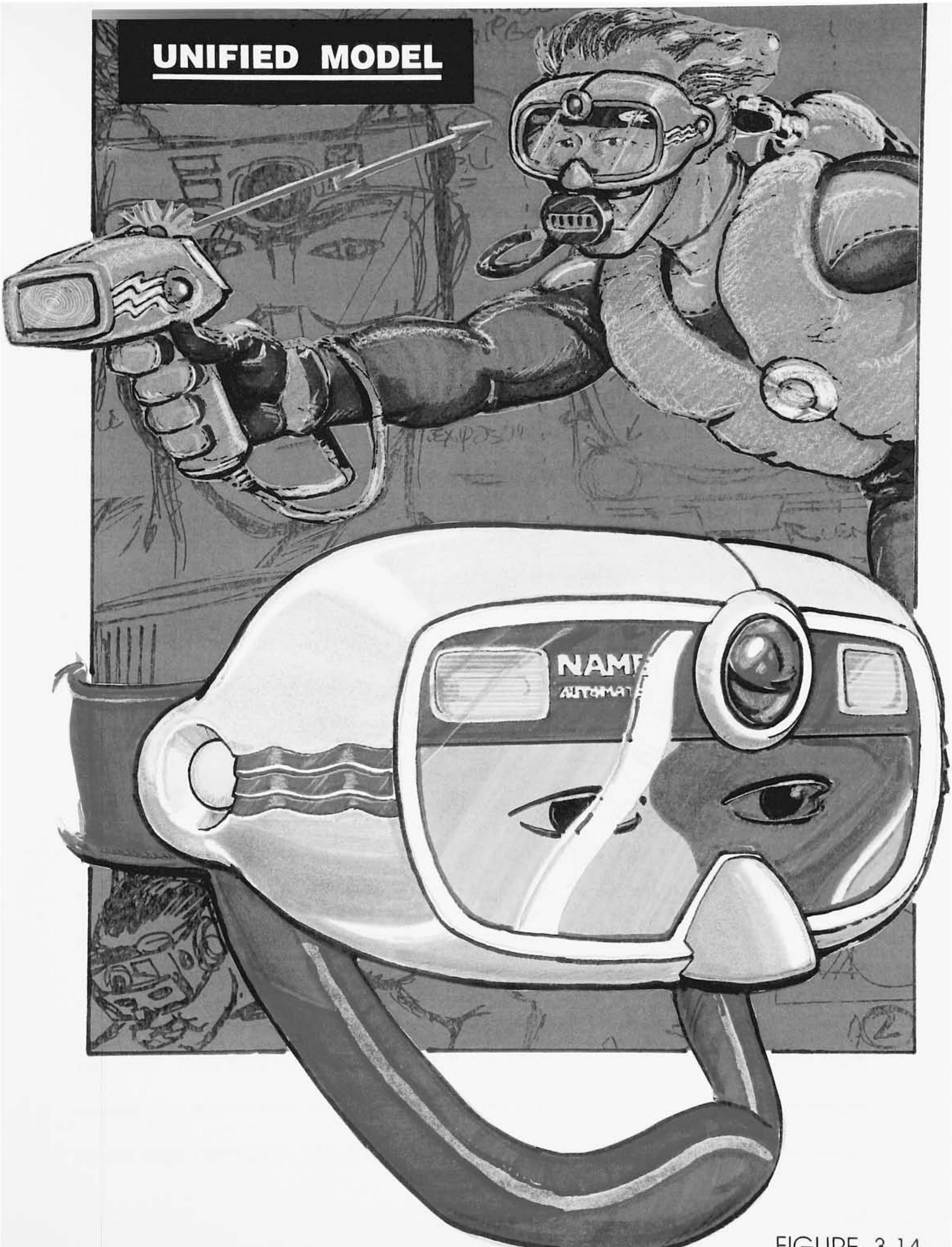


FIGURE 3.14

Unified Model

Figure 3.14 shows a close up of the Unified Model, the first design to meet all of the desired aesthetic qualifications. Its shape was simple and harmonious—the camera section was unified with the mask housing, but separate from it in a way that enables the components to overlap and fuse. The apparent bulk of the camera module was reduced by having part of the module enclosed behind the port. Bands of rubberized texture lead to the controls on the housing towards the rear of the unit. The shutter buttons were located here so that pushing a button would not rock the mask, compromising the seals underwater.

This unit had an appropriate shape for use in the water and looked comfortable mounted on the diver's face. Possible techniques for using the camera, as well as the variations in the design and technical adaptations, all started to develop. The only problem was in getting this design off the paper.

Bringing the unified model into three dimensions was difficult. Although the shape and style were very close to the desired aesthetic, because of the perspective of the drawings, with the size of the original foam camera module, there was no way to make a 3D sketch model without substantial alterations.

In the drawings, the port and the camera module are both much wider and narrower than they could possibly be in reality. In trying to sculpt the same form around the plaster cast, using the standard volume for the camera module, the model would have been huge and possessed a tremendous volume of air within the mask.

The only way of capturing the flavor of the design in an attainable form was to rearrange the components.

The first adjustment made was to re-configure the camera module. Although the module was not wide, it protruded too far from the brow for this design. A curved film transport configuration—similar to Figure 3.4_4—was needed to use the space more effectively. Wrapping the the film path around the temples reduces how far the camera module would protrude past the port, and minimized the discrepancy between the width of the mask and the width of the camera module.

The second change made to the camera module was to confine most of the mechanical and electrical components to the top of the module. This made better use of the space available by relocating existing mechanical and electrical elements to a more convenient location. Setting these components in the top of the module allows the bottom to be reduced. With a smaller bottom, the module can be located farther down on the forehead without protruding into the diver's field of view, which reduced parallax error. Since the port overlaps the bottom of the module, the same modifications allowed the port to be located closer to the diver's eyes for a reduced volume of air in the mask. With these alterations, a model that is based on the unified model could be realized.

The sides of the unified model also presented a challenge. For the housing and controls to protrude so far back on the head would require a very large housing with waterproof passages for the wires to run from the controls into the camera module. The wire would have to leave the module, run under the seal to the buttons, and be securely mounted and waterproofed. Since every opening is a potential source of leakage in the mask, it is an advantage to have as few as possible. For this reason, the buttons were moved to the temples, so that they could be directly connected to the camera module.

These alterations allowed for a more compact version of the unified model to be created. It was simple and elegant, used the available space well, met the aesthetic goals, and was technologically feasible. This "preliminary model " achieved the unity and fusion of elements that the original sketch of the unified model had presented.

Preliminary Model: Technical Considerations

At this stage the design became sufficiently clear to warrant the finalization of secondary technical issues that had been avoided up to this point. The details of the size, shape, location of the camera module had been firmly established for some time. However, how the mask would be attached, the variety and placement of controls, and how the film would be loaded into the camera were still to be determined.

Exotic kinds of straps had been considered during the design process. The most unique of these was a full head cowl that would attach to the back edge of the housing. The design that seemed best suited for this preliminary model was a variation of the standard split strap configuration; to keep the contours of the housing unit smooth, this design has the connector to the mask housing on the inside of the mask. The connector is located in line with the eye on the interior side of the housing but is concealed by the opaque black skirt-seal. The mask can be tightened by squeezing the clip located on the ends of the strap and pushing back. This streamlines the housing and eliminates the "flaps" that can occur when the ends of the straps get out of their holders.

How to trigger the shutter proved to be a more complicated matter. Regular push buttons would be the obvious choice, except for the unavoidable problem they have underwater; as a camera descends the pressure of the surrounding water increases and, at a certain depth, this pressure is sufficient to completely depress the button without the diver even touching it. Controls that are rotated or slid do not have trouble with pressure since the water can only push. Shutter buttons are traditionally pushed, so it was desirable to come up with some configuration that would allow this otherwise simple method to be retained.

The preliminary model turned the water pressure from a problem into a distinct advantage by using dual electronic pressure sensors located at the temples as shutter buttons. This configuration can eliminate the problem by using the difference between the pressure readings of the two sensors to determine when to trip the shutter. If the unit is in the water, the pressure of the right and left sensors are greater than atmospheric pressure but they are equal. When the photographer presses one of the sensors (whichever one they prefer) the sensor readings become unequal; it is this non-zero reading that signals the microcomputer when to take a picture. The pressure readings can also be used to determine the diver's depth at any instant, which could easily be imprinted with the time on the film with the use of a standard data back. No other underwater camera has this capability.

The design could be made truly "hands-free" by incorporating some kind of device that could enable the diver to trip the shutter without the use of their hands. This requires finding an alternate, unambiguously controllable signal. Unfortunately, almost all of the ways to achieve this are highly unconventional.

Biting down on the snorkel or mouth piece is one such useful signal, as is pressing a button on the inside of the mouthpiece with the tongue. Sound could be use as a trigger; however, since the mouthpiece restricts the mouth, the signal would have to be a grunt (or a hum). Eye-blinking could potentially be used, but this would require sensors pointed at the eye and would have to distinguish from normal eye movement. It is questionable how ready the general public is to lick, grunt or blink in order to take a picture. Building any of these features directly into a unit could prove complicated and overly expensive, since it is unlikely that everyone would be comfortable triggering the unit in the same way. This obstacle is circumvented by building a remote sensor into the dive mask to pick up a short-ranged infrared signal from any one of a variety of signaling devices. Other useful controlling devices could include hand-held flash units, wrist panels, or remote buttons located on a dive computer.

With the addition of a remote sensor onto the unit, the preliminary model becomes the main component of an underwater camera system that can be extensively and easily customized to suit any individual diver's tastes.

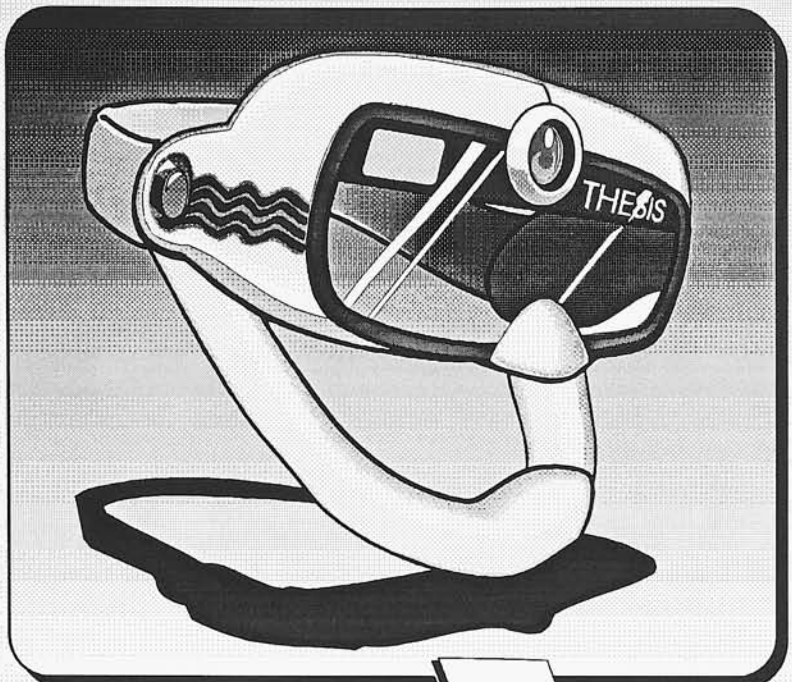
The film could be loaded in any one of several different methods. A simple curved door on the back of the camera module was chosen. The hinge is located on one side along the flat edge closest to the temples. The skirt completely covers it, except when film is being loaded, when the skirt is folded back and held in place by the weight of the strap. The locking device is located opposite to the hinge and is flush to the surface of the door. The door rests on the forehead when in use.

The final decision at this stage was what to call the new design. The preliminary design was sufficiently real to warrant an appropriate name. It was important that this name precisely stated the nature of the design; an underwater camera fully integrated into a dive mask. After examining many possible names and acronyms with increasing frustration, it was suggested that the best alternative was simply to describe the new unit simply, directly, and clearly. The preliminary model became known as:

Compact Underwater Photographic Headgear

(or **CUPH** for short).

PRELIMINARY CUPH MODEL



- THE NEW DESIGN (BELOW) REALISTICALLY CAPTURES THE FLAVOR OF THE UNIFIED MODEL (LEFT).
- THE NEW DESIGN MAKES USE OF A SIMILAR OVERLAPPING TECHNIQUE TO MINIMIZE THE VISUAL SIZE OF THE CAMERA MODULE. THIS PRODUCES THE FUSION BETWEEN THE MASK WITH THE CAMERA.
- THE DUAL PRESSURE-SENSING SHUTTER BUTTONS HAVE BEEN MOVED TO THE TEMPLES.

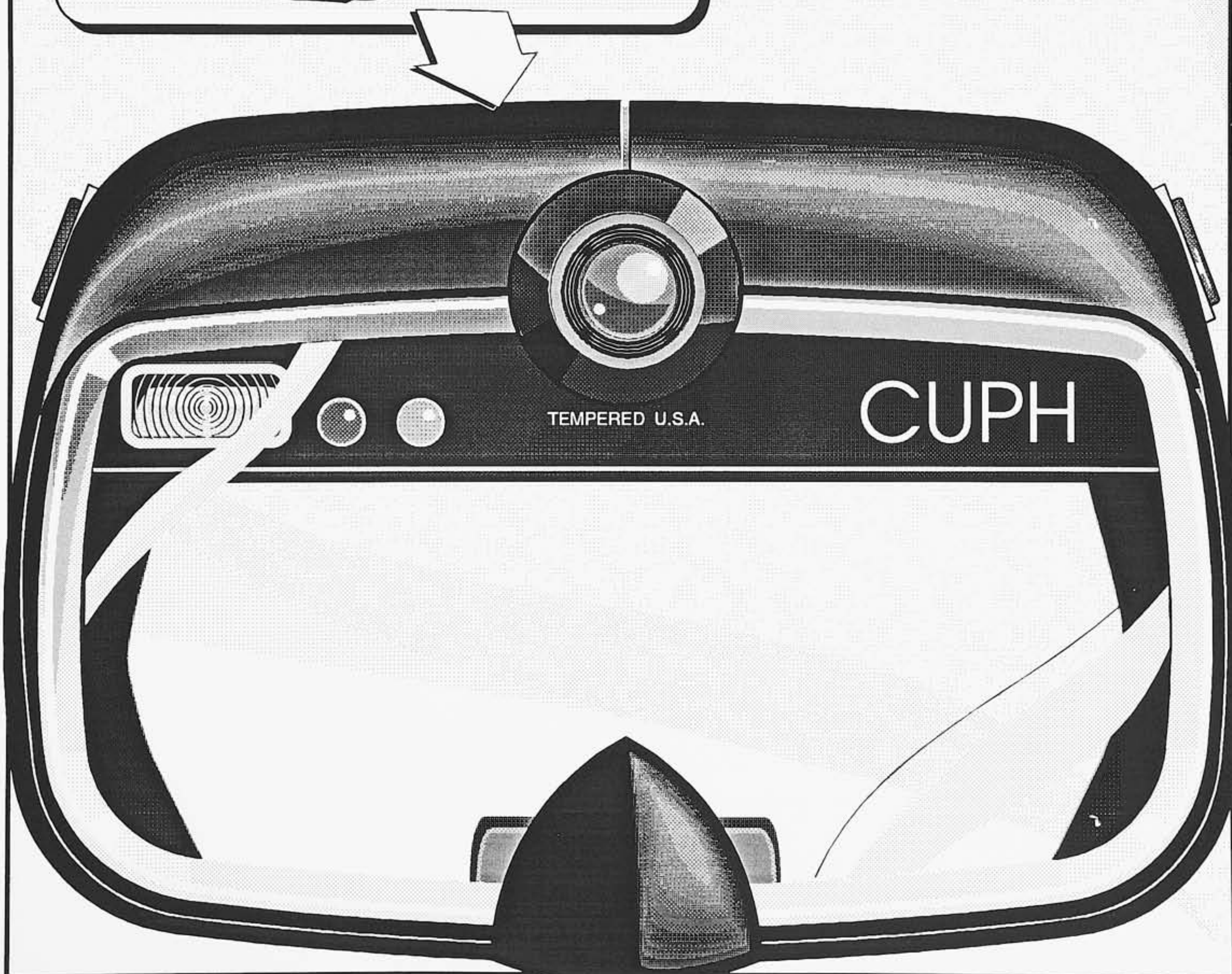


FIGURE 3.15

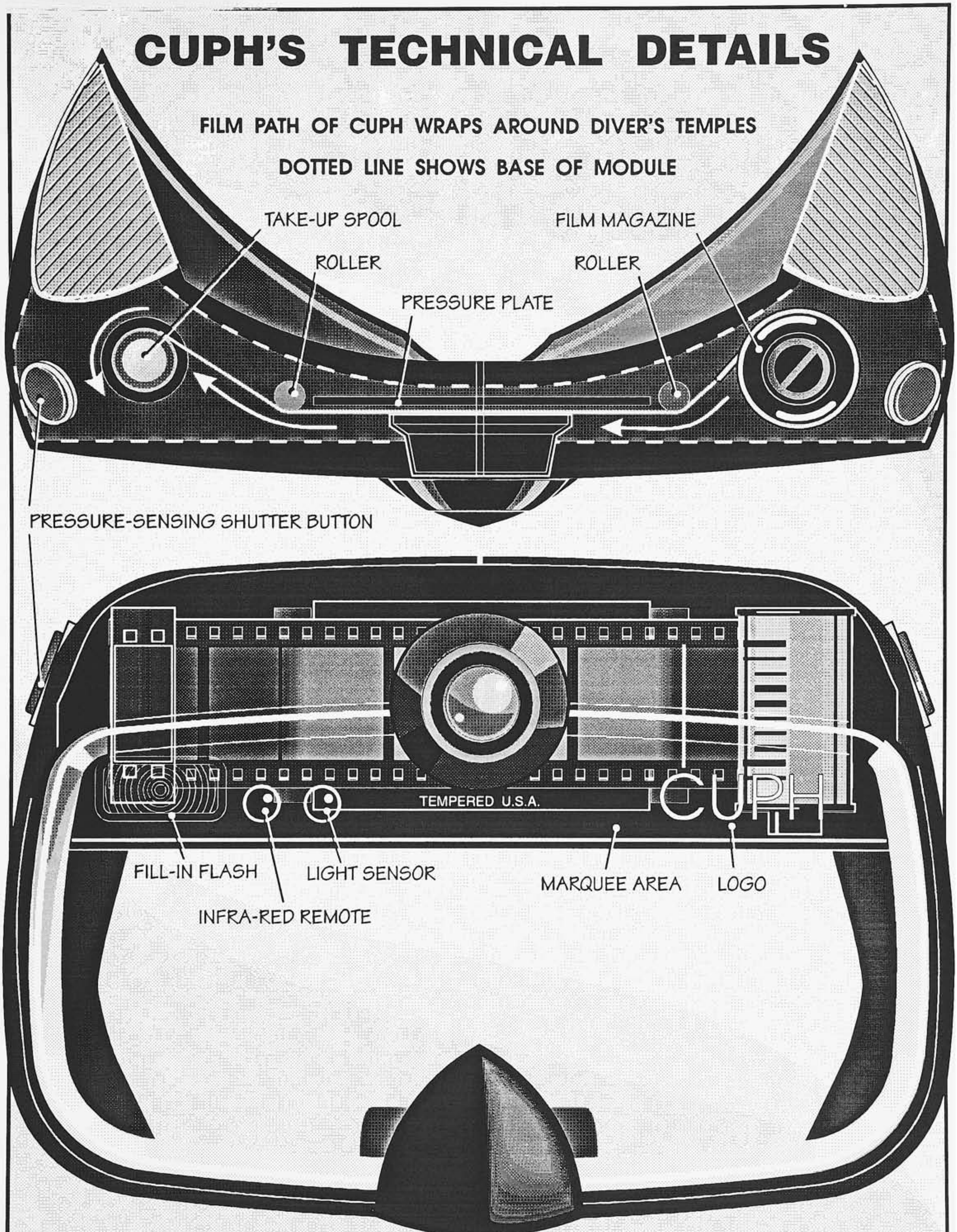

CUPH'S TECHNICAL DETAILS
FILM PATH OF CUPH WRAPS AROUND DIVER'S TEMPLES
DOTTED LINE SHOWS BASE OF MODULE
TAKE-UP SPOOL
FILM MAGAZINE
ROLLER
ROLLER
PRESSURE PLATE
PRESSURE-SENSING SHUTTER BUTTON
TEMPERED U.S.A.
CUPH
FILL-IN FLASH
LIGHT SENSOR
MARQUEE AREA
LOGO
INFRA-RED REMOTE

FIGURE 3.16

Shows the size of the CUPH model in relation to a roll of film.

Film is loaded from the back of the unit.

The unit can securely rest on the lap when film is being loaded.

FIGURE 3.17

Above: CUPH thesis model in progress being tried on for size.

Right: Side view showing the placement of the shutter button in relation to the hand.

Below: Thesis model being worn by a small female.

FIGURE 3.18

POSSIBLE NAMES FOR THE NEW DESIGN

It is essential that the name properly expresses both the aquatic and photographic nature of the unit.

UNDERWATER...CAMERA

AQUA VIEW AQUA EYE AQUA CAM	PHOTOQUATIC PORT PHOTOQUATIC GOGGLES PHOTOQUATIC MASK	3RDi THIRD-EYE
DIVE EYE DIVE VIEW	CAMERAQUATIC MASK CAMARINE	DEJA VIEW
HYDROCAM HYDROPHOTO	HYDROPTICAL UNIT HYDROPTICAL PORT	SYNERGYST SYNER-GYST

None of the above seemed appropriate, so other options were examined.

ACRONYMS:

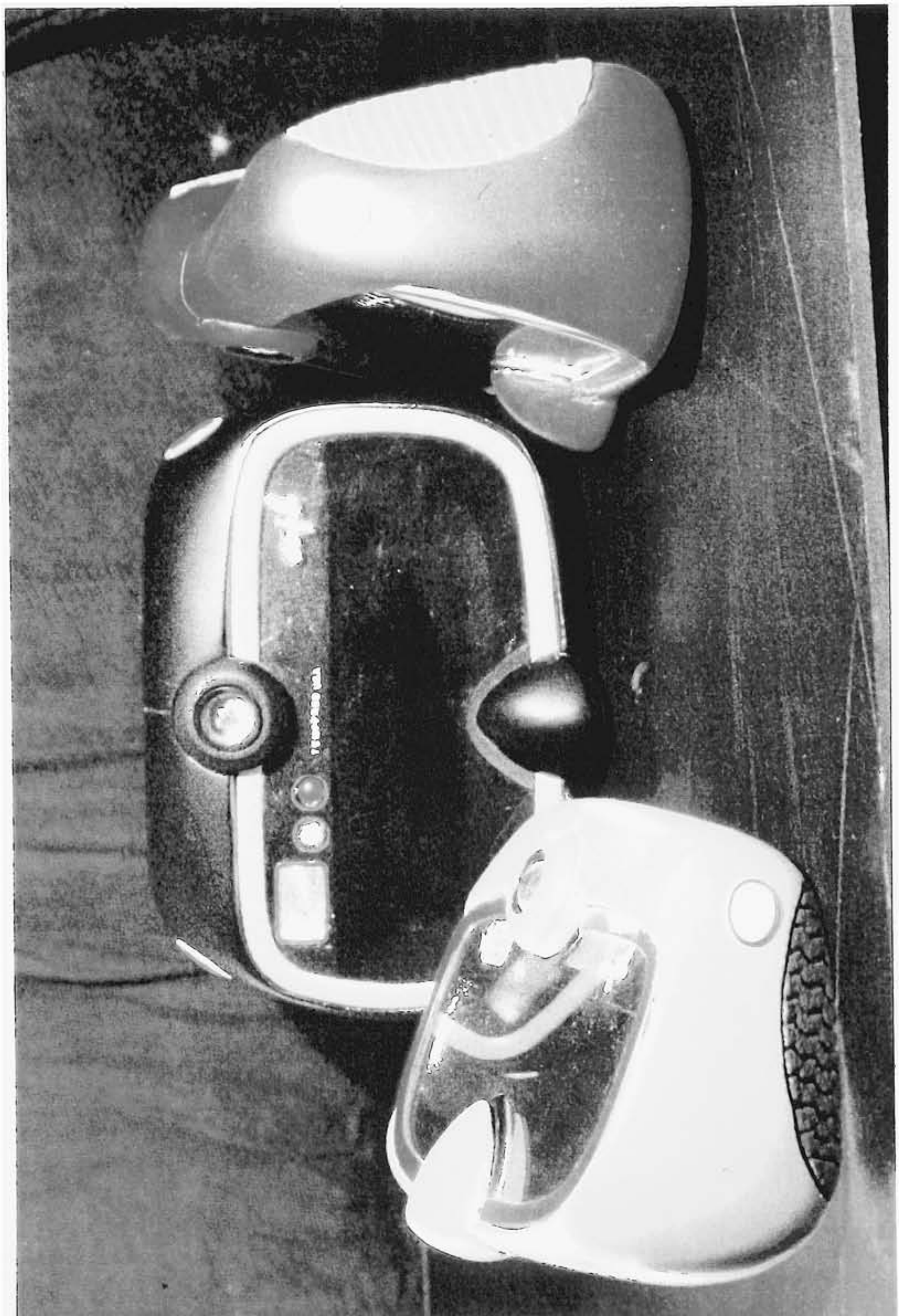
Synergystic Underwater Photographic System	Compact Underwater Photographic Headgear

Compact Underwater Photographic Headgear
or CUPH (pronounced CUFF)
concisely states what the unit is all about,
and the abbreviated form sounds 'right'.

CUPH C.U.P.H. Cuph cuph c.u.p.h.

These letters could be exaggerated to create an effective logo.
'CUPH' looks like a fish while 'Cuph' has a wavelike motion to it.

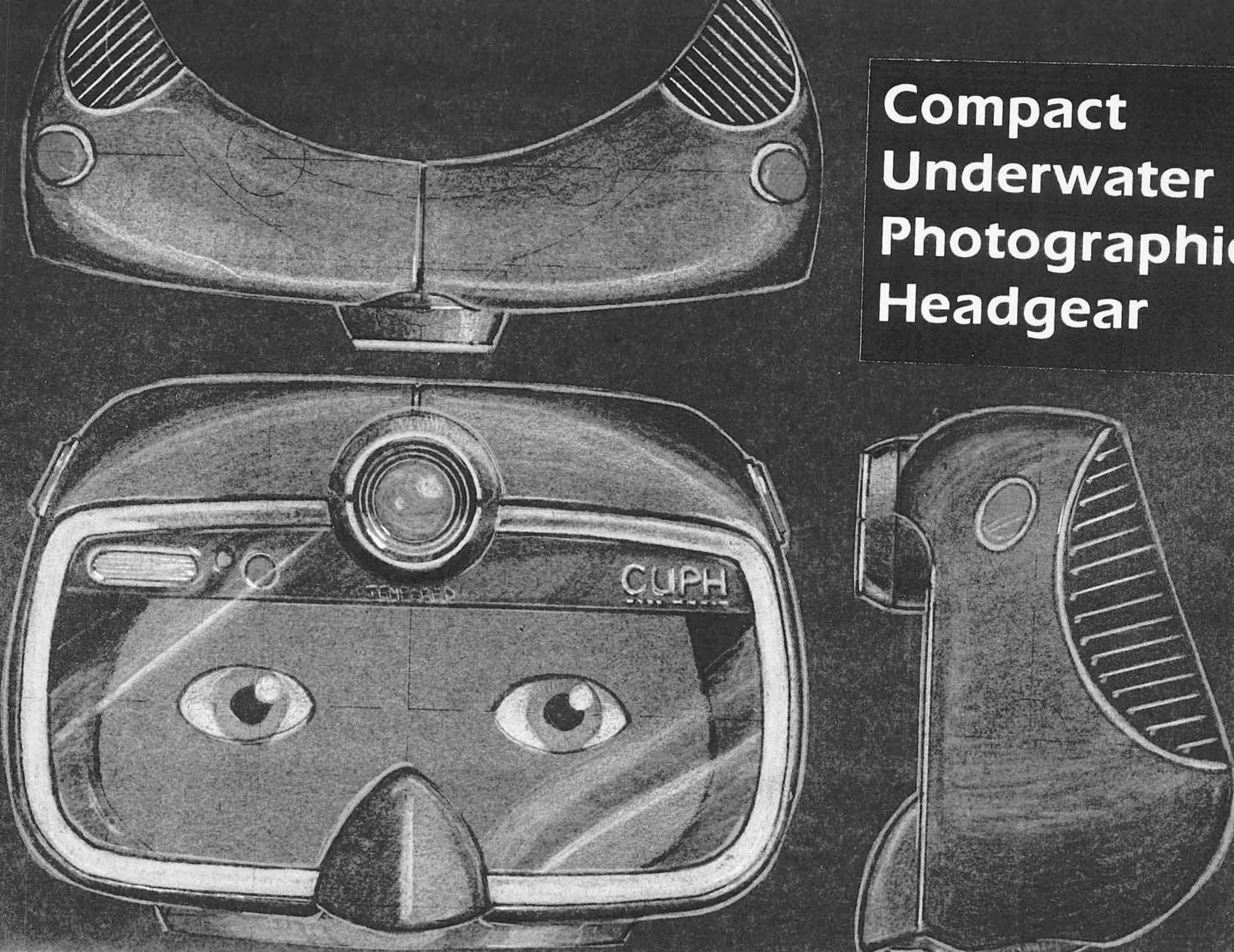
FIGURE 3.19



Final models that were displayed at thesis show.

FIGURE 3.20

Compact Underwater Photographic Headgear



COMPACT UNDERWATER PHOTOGRAPHIC HEADGEAR

The final model of the CUPH is shown in Figure 4.1. The form clearly reflects the desires and motivations that fueled the development of the Aquatic 35 mm Format; a harmonious fusion of camera and dive mask that is fully functional, simple, elegant, and compact, that looks new and exciting and somewhat mysterious, and possesses room for future growth.

Aesthetics

The CUPH's aesthetic borrows liberally from its roots as a dive mask and a camera. Its shape is well rounded and nautical with several hard edges for contrast. It is just large enough to function properly as a dive mask and houses the camera module in a very compact manner. The CUPH's form is appropriate both for the aquatic environment it must work in, and for the structure of the human face. Its masses are gently rounded and streamlined like the body of a whale or a dolphin. These masses also correspond to the major structures of the face that they obscure: the brow, the cheekbones, the bridge of the nose. In mimicking the structure of the face, the housing also highlight the diver's eyes.

The geometric centers for the curves of the housing are located at each eye for both the front and the sides of the unit. Underwater, the eyes are the only part of the diver's face that retains its ability to be expressive; Under these circumstances communication is naturally limited to hand and body gestures and eye movements. For this reason highlighting the eyes facilitates communication and "gives back" to the diver a face that is otherwise totally obscured by equipment.

The CUPH also draws attention to the eyes with the bezel that holds the glass port in place. The bezel brackets the face; it provides color contrast along the borders of the diver's field of vision, while worn. Since the bezel is relatively close to the diver's eyes it's color should be vivid at any depth. It also provides optical contrast on the overall unit, while making the onlookers create closure of the visual gaps over nose and lens, to energize and complete the shape.

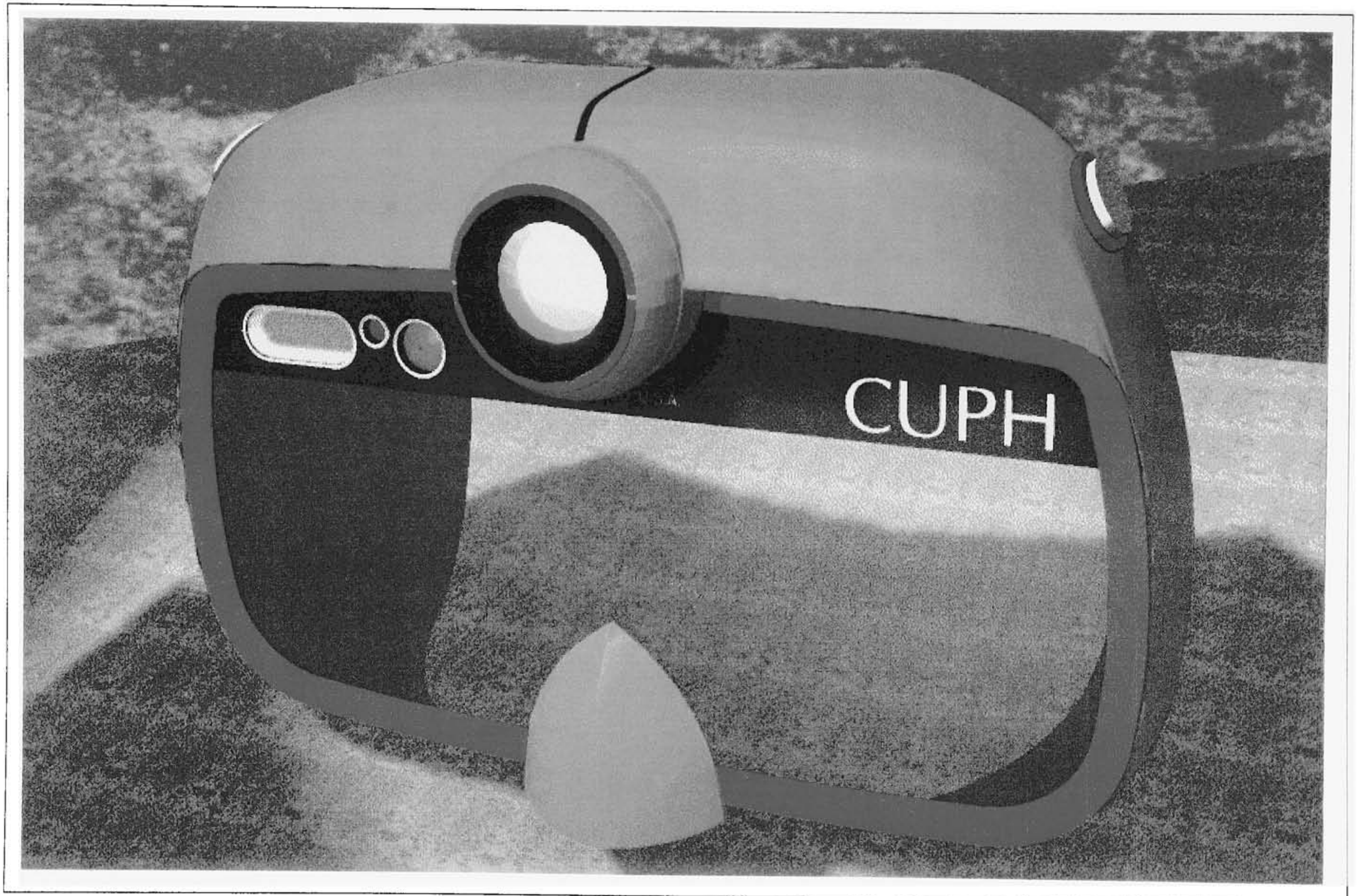
The way the housing feels is extremely significant. Since it can not be seen by the diver when worn, the main interface between the diver and the camera's devices is textural. The curves of the CUPH's sides fit comfortably in the palms of the hands and provide a convenient location where the hands can rest while operating the camera. The texture on the sides leads the diver's fingers towards the shutter buttons at the temples. This is the most natural location for the controls, since a finger lightly touching or scratching the temples is commonly associated with thinking or remembering. This gesture says; hmm...let me think; or, eureka!!! that's it! I've got it!

Most cameras use textural areas to easily distinguish their parts. This usually takes the form of leather coverings or rubberized grips. The rubber textural areas at the temples of the CUPH continue this tradition. They provide contrast in texture to the smooth glass and plastic elements of the remainder of the body. In addition to these other functions, they offer an easily adaptable styling feature. Individual units can painlessly be personalized.

The plastic housing can accommodate a wide range of color schemes and graphic treatments. Black is a very successful and obvious choice of primary color for the housing, since people associate the color black with cameras. Supplementing the basic body color, any high contrast, vivid nautical color scheme can be used to make the buttons, logos, and bezel stand out. The CUPH's housing also allows for graphic customization on the rounded masses by applying pictures and patterns in ways similar to jet skis, goalie masks, and skateboards. Unusual color schemes may cause some confusion (interest) as to what exactly the CUPH is.

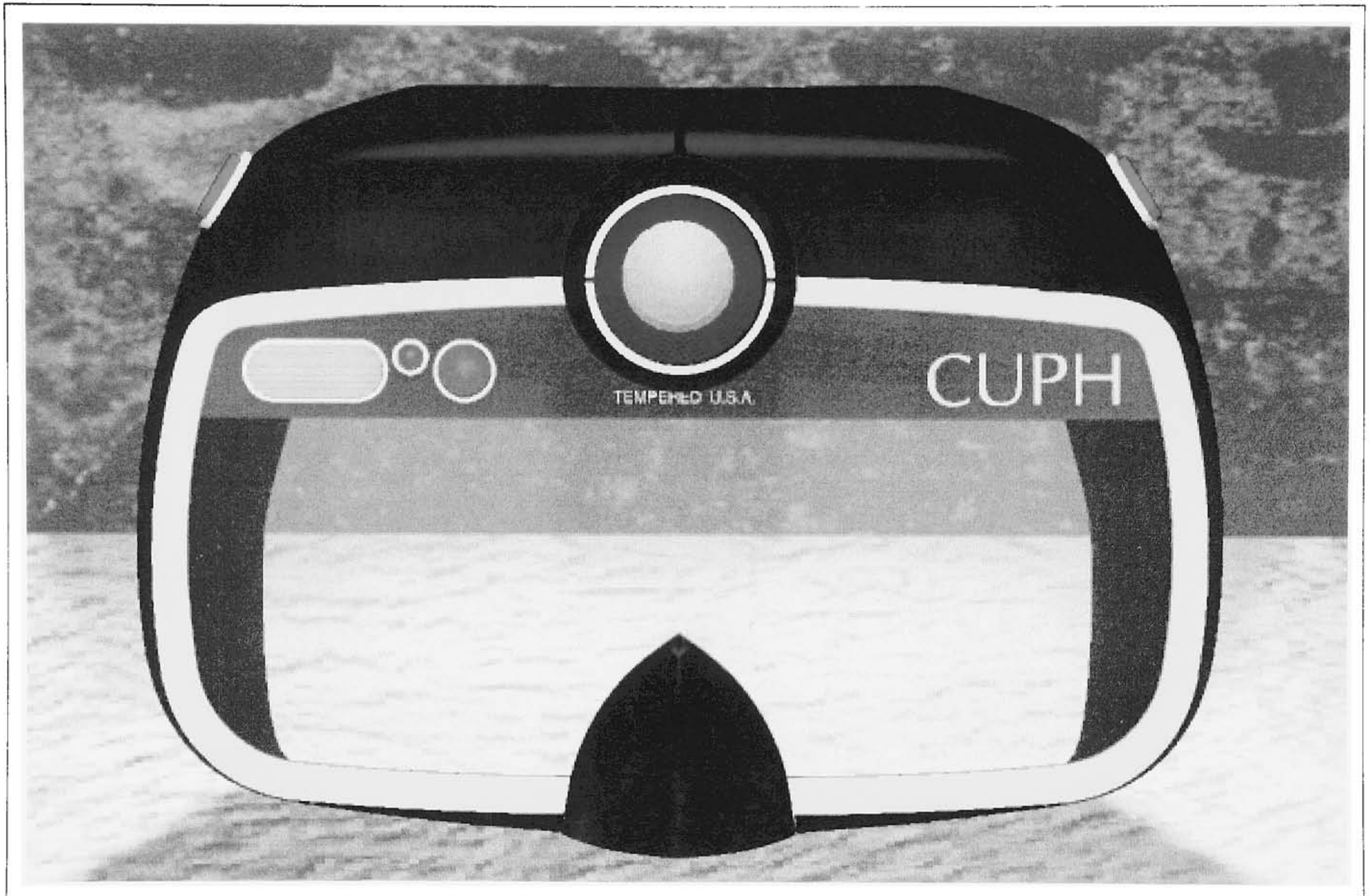
The CUPH may not immediately be recognized as a camera because it is so different from the standard 35mm camera format. It could be mistaken for just an ordinary dive mask. This is not a problem. The CUPH will be used underwater, where no one but the diver using it need know it is there. Distracting other divers with your equipment is no benefit when you are underwater. Drawing attention away from the dive is detrimental and dangerous.

Out of the water at close inspection, the CUPH's strange, new appearance is an advantage. It will attract attention before and after the dive. Its function can easily be explained. After recognizing the CUPH as a camera, the unit will seem even more interesting. Oh, that's what it is! Can I use it next?



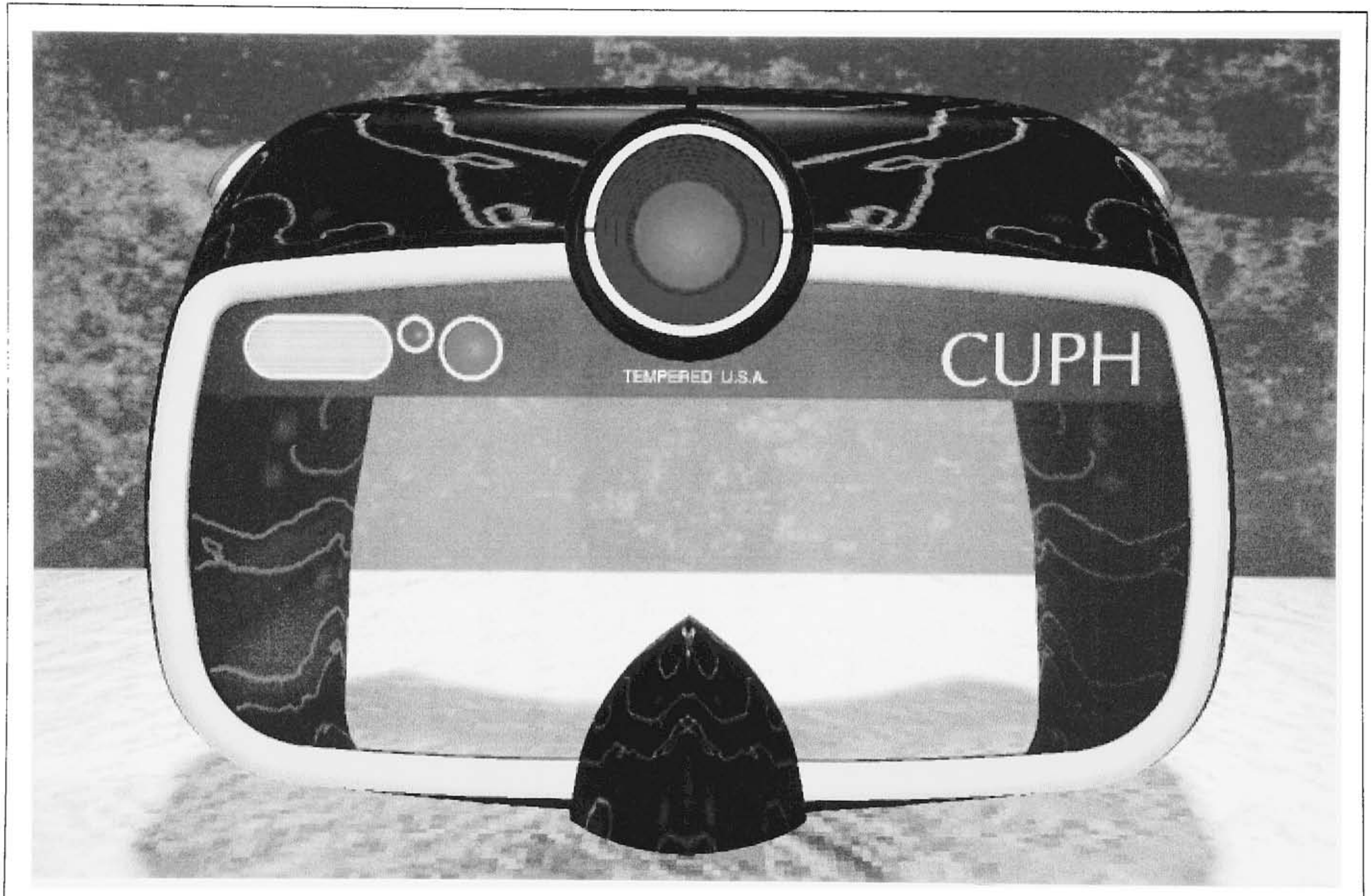
Compact Underwater Photographic Headgear- Perspective view of basic unit.

FIGURE 4.2



Compact Underwater Photographic Headgear- Basic black color scheme.

FIGURE 4.2a



Compact Underwater Photographic Headgear- Graphics applied onto housing.

FIGURE 4.2b

Use Cycle

The CUPH eliminates the major difficulties in posture, viewing, and operating conventional equipment that face the novice underwater photographer without adding any new problems. Great effort has been made to ensure that the CUPH is very easy and natural to use.

Figure 4.3 illustrates the CUPH's cycle of use. With no film loaded, the camera is in "off" state. While on land and the CUPH is dry, the film is loaded through a door on the back of the camera module. When the film is inserted and the door is closed and locked, the metal of the film canister closes a circuit that initializes the camera; it reads the film's DX code on the canister, sets the film speed into the micro-computer's memory and then the transport system winds the film (or pre-winds) to the first exposure. This procedure does not differ from the loading of a conventional underwater camera, and is much simpler than loading a SLR and inserting it into a waterproof case. With the film properly loaded, the unit can be treated as a dive mask, until a picture needs to be taken.

With the CUPH in place, the diver enters the water as if wearing a normal dive mask. When the CUPH is submerged, it senses that the pressure is now greater than atmospheric pressure; this turns the camera *fully* on; it will remain on for the duration of the dive. The sensors will constantly be taking both subject and background light readings, so that at any moment it has the proper exposure, should a picture need to be taken. This also gives the camera additional useful exposure information that can reduce the time needed for calculation when a picture is to be taken. This anticipates

THE CUPH TASK CYCLE

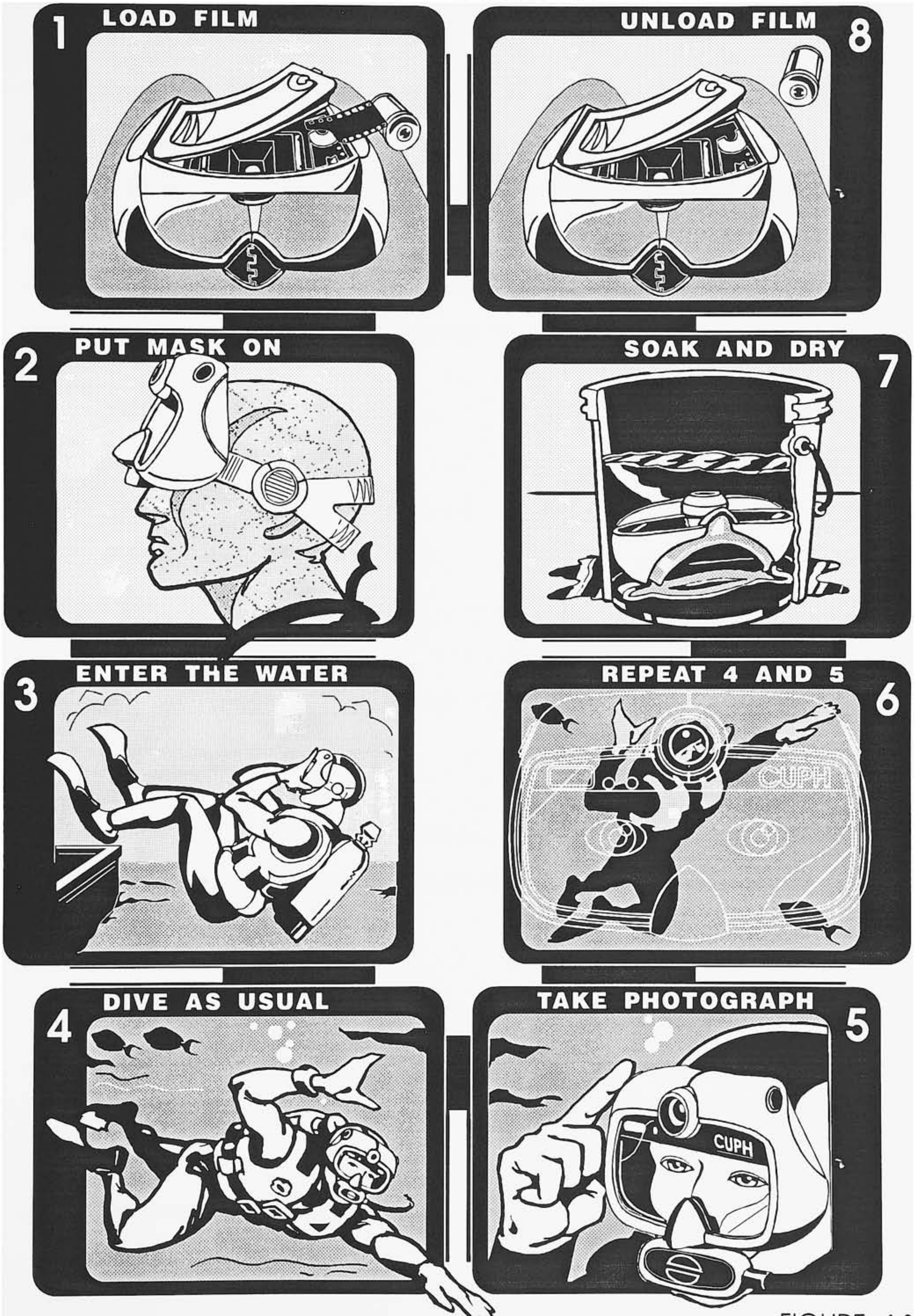


FIGURE 4.3

the photographer. The diver can freely swim around until a desired photographic subject is located. Any object greater than arm's length away—approximately 3 feet—will be in focus. Using ambient lighting, the diver looks directly ahead at the subject, roughly composes the picture in the field of view and presses one of the shutter buttons on either temple to take the picture. Then the diver is free to move on to the next subject, perform tasks or just enjoy the dive.

In darker waters, if an external flash unit is required, the procedure is similar; first the diver looks straight ahead and composes the shot, then points the hand-held external flash unit at the subject at an angle, and finally presses the trigger on the flash unit. This sends a signal from the flash unit through the water, which is received by a sensor on the CUPH and triggers the shutter. There is a set delay from the time that the signal is sent from the flash to the time it sends out the light for the photograph, to allow for the camera to make its settings and open the shutter. Then, the diver continues on just the same.

If the film runs out an audio signal (beep) will indicate the end of the roll. If the diver forgets and tries to take another picture, the beep will signal again as a reminder that the roll is finished.

Once the dive is over, and the diver comes back to the surface, the ambient pressure once again reaches atmospheric pressure and the unit's constant-ready mode is turned off. If there are still unexposed frames on the roll, the camera will stay on for five minutes and will then shut itself off, until the shutter buttons sense something other than atmospheric pressure. If the film has all been exposed, the camera will rewind the film back into the film magazine. This prevents the diver from having to listen to the sound of rewinding across his temples underwater—the noise of the motor will be less bothersome if the CUPH is not being worn when rewinding.

The camera must be thoroughly dry before unloading or reloading the film. It should be soaked in a bucket of fresh water to loosen up the salt deposits, then dried before opening. This procedure is consistent with existing equipment, and is necessary to prevent water from dripping in past the seals when the camera is open.

The maintenance of the seals and gaskets are also consistent with existing equipment and can be performed back on dry land or in a boat safely away from stray water.

Even though it has been designed for underwater use, photographs may be taken in air with the CUPH, in the water at the surface, on boat or on land, provided that there is still film in the camera. The temple buttons must be pressed simultaneously to activate the camera (this tricks the camera into the constant ready state if it has been idle) then the picture may be taken, either holding the CUPH in position on your face, or pointing it at the subject. The exposure on land should turn out well, since the underwater "spot" exposure program is more conservative than a land program. (If a camera is programmed to expose exclusively for the subject, whether it is on land or underwater makes little difference. Unlike the typical average metering, it functions well in either case.)

The limitation of the maximum number of exposures on a roll of film is not bad. They are the same restrictions that most conventional underwater equipment has to face. Everything divers do underwater is limited, since they have a fixed amount of air in their tanks. If the typical duration of a dive is a half hour, with a 36 exposure roll of film loaded into a CUPH you cold take a picture every minute and still have six exposures left.

Benefits of CUPH

Compared to the drastically reduced myopic view of conventional viewfinders underwater, CUPH and the new aquatic format offer dramatically increased performance. Using a CUPH, a diver has the maximum field of view a dive mask offers, whether taking a photograph or not. None of the view is obstructed by either the diver's hands or the back of the camera; in essence the camera has become invisible. The diver is able to take full advantage of peripheral vision, even when composing a picture. This reduces danger from unseen obstacles and sudden changes in the environment. In addition, since the diver is still seeing with both eyes, it is a full stereoscopic view. Depth perception is retained and a sense of the distance to the subject being photographed is possible.

Another distinct advantage of the CUPH is that since the hands are freed from the task of having to hold the camera for the entire duration of the dive, a diver has much greater freedom and mobility. When not taking a photograph, a diver is able to swim exactly as if wearing a traditional dive mask and not carrying a camera at all. Besides increased mobility, this allows the option of performing a variety of non-photographic tasks during a single dive. Conversely, the diver that had not intended to take a photograph on a particular dive, when wearing a CUPH, can take one if the need suddenly arises.

The camera in a CUPH is there if needed, and demands no extra attention otherwise. When wearing a CUPH underwater, a person—whether amateur or professional—can focus entirely on the diving experience. The person's attention does not need to be divided between watching the surroundings and trying to use equipment that is unnecessarily demanding. This increases both diver safety and the performance of the camera.

It is assumed that the value of the images obtained underwater will be significantly high and the frequency of use underwater will be sufficient to warrant an appropriate design specifically for use underwater.

For the vast majority of casual photographers, holidays, birthdays and an occasional vacation, result in one or two rolls of film a year. If recreational divers are willing to spend hundreds of dollars—minimum—on a underwater camera, and a thousand or so dollars on a trip, and equipment for the express purpose of recording their diving experience, they are likely to shoot more rolls of film than most families would in several years—good results would prompt them to shoot even more. The justification for a specialized design, clearly, is here.

The most apparent limitation to this new design is that it is fully aquatic. Double-duty as both a *general-purpose* land camera and a diving camera is not practical with this format. Although the CUPH will function both on land and in water, it is difficult to imagine someone taking pictures around a Christmas tree or at a birthday party with a diving mask on.

However, this is not to say that there are no in-air applications that are appropriate for this new format. In any situation where it would be convenient to have a camera but a person's hands are otherwise occupied, this "hands-free" format could be enormously useful. For example in the sports of skydiving, rock climbing, cross-country and down-hill skiing, bike racing, surfing, bungee jumping, spelunking or any other situation where the hands are busy and a static standing posture is impractical, this format could easily be applied. It could also be used by inspectors in industries to document quality control on a production line or to record damage to large equipment. Meter readers could use it to take accurate, unambiguous readings and delivery people could use it for identification purposes. Individuals with disabilities that prevent them from being able to use conventional equipment could also benefit from an application of this concept.

In each new application a camera module that is appropriate for that use would be chosen. The design of the housings would vary with different uses as well. The film size could be reduced, or digital technology could be used to make more units less conspicuous for land use. The potential uses of this concept are staggering.

New Potential

Of course, the CUPH format also creates new potentials for underwater photography. It simplifies the demands of the task to such an extent that any divers interested in taking underwater photographs, regardless of their skill level, do not have to be frustrated by the difficulties that conventional equipment present.

A market for CUPH rentals in resort areas could easily be developed. Since the equipment is so user-friendly, tourists could easily record their experience with little difficulty or special training. Owning a dozen CUPH units in a resort location could become a very lucrative business that would quickly pay for itself.

In addition, CUPH presents new possibilities for existing professional underwater photographers. Now, besides their usual equipment, they can take down another camera unit that takes up 'no' space and demands little extra effort—in a similar way to how a professional photojournalist may take with them a point-and-shoot camera in their camera bag, just in case. This allows for a greater number of photos to be taken without reloading and allows for greater spontaneity.

CUPH also presents a platform that professional-level equipment may one day be built on. Additional flashes, interchangeable lenses, and a variety of program modes could easily be built into the CUPH to allow for greater creative control. Each new addition would require solving new, more complex design problems, but none of them should prove to be insurmountable. For example: adding a macro lens for close-up photos is a logical next step for the CUPH so that close-ups of coral and tiny creatures could easily be captured. Attaching a new lens would be extremely easy, but how do you give the diver the ability to preview the image through the viewfinder (using two eyes) if the picture corresponds to only a small fraction of their field of view?

Marine biologists, underwater archaeologists, police divers, and industrial divers can all gain new ability using CUPH. Before, many professional divers were prevented from taking a camera underwater when they dove because they had primary tasks that required their complete attention. If they did take a camera, it would deter them from performing the tasks. They would have to try to tell someone what they had seen (if that information was important), or two divers would have to be sent down, one to do the work, the other to operate the camera. With a CUPH, these divers could perform their tasks and, if necessary, record their progress or other important information each from their own point of view, using time and attention more intelligently. For example, in the case of police divers, they would not just have to search for a sunken car wreck, or a body, and then surface to tell people; they could find it and record how and where they found it before surfacing.

A marine biologist could use a CUPH as a 'notebook' for recording for further study later information that was observed during a dive, without using intrusive equipment. Similarly, marine archaeologists could record a site's location and depth, as well as stages in excavation, time and duration of the dive, with ease.

The development of the CUPH also creates an entirely new direction for other diving equipment. In a way the CUPH is a head mounted microcomputer that is capable or recording images underwater and precisely keeping track of a diver's depth at every stage of the dive. It could easily be made to keep track of the diver's position and the duration of the dive and amount of air in the tanks. All of this information could be displayed on a control panel within the dive mask to produce a new kind of dive computer.

The concept of integrating an underwater camera into a dive mask is both feasible and attainable now. The potential uses for the CUPH are vast. Its design satisfies many needs.

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