DIVING DATA BANKS WORKSHOP

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DIVING DATA BANK WORKSHOP - OPENING

Introductory remarks of welcome were made by CDR C. A. Harvey, MC, USN, CDR R. L. Sphar, MC, USN, Officer in Charge, and by Dr. Charles F. Gell of the Naval Submarine Medical Research Laboratory. Dr. Harvey then expressed appreciation for the efforts of Mr. James W. Parker as well as the secretarial staff of the Laboratory for the preparatory work in advance of the meeting. The meeting then was turned over to Dr. Peter Barnard, the Workshop Chairman.

SESSION I: EXISTING DATA BANKS

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A. SURVEY OF EXISTING DATA BANKS: CDR CLAUDE A. HARVEY, MC, USN

The Decompression Data Bank Committee of the Undersea Medical Society recently prepared a small article (published as a special insert in the September/October 1973 issue of Pressure, the Newsletter of the Undersea Medical Society) which gave a brief description of thirteen "Data Banks" that contained information pertinent to diving medicine, physiology and equipment. The first problem we faced in preparing the report was defining the term "Data Bank". A data bank, obviously, can be anything from a collection of information in a file drawer, to the most sophisticated computerized system of filing, updating, searching and retrieving, and analyzing data.

We will concentrate on some of the more formalized data banks since this is the type of bank that the speakers here will present. Data banks can be designed for internal use where the user understands what is stored, or they may be designed for outside users, in which case it is necessary to develop an interface. Again, data banks may be oriented to the individual user with the information stored in such a fashion that upon appropriate request it can be retrieved, or the data bank may be oriented toward reports, in which case the bank collects data, summarizes and/or analyzes it, and disseminates the results in report form. Some banks have slow access and some have very quick access; some banks require only one or two operators, while others have sophisticated equipment requiring several operators.

Banks are developed for many purposes: literature files containing articles, reports and books that are pertinent to a given field; records of specific experiments, such as testing physiological tolerances and responses; data from some group undergoing a common experience such as the dive records assembled at the Naval Safety Center; accident-reporting centers; range and characteristics of human physiological responses to stress; and listings of individuals who have some expertise to offer; and facilities and equipment available for use. It was necessary to select certain data banks to be represented in this workshop, as it was necessary to select data banks for the report in Pressure.

Of the 13 in the Pressure report, six will be taken up in this workshop. I will briefly mention the other seven.

The U.S. Air Force School of Aerospace Medicine has records of patients treated in eight U.S. Air Force chamber facilities for altitude casualties since 1 January 1965. This data bank has not been prepared or interfaced for dissemination.

The National Underwater Accident Data Center at the University of Rhode Island has a primary mission of acquiring data on skin-and scuba-diving-related accidents involving U. S. citizens.

The Human Physiology Data Bank at the University of California at Davis collects and stores for future computer analysis records of human physical performance under environmental stresses.

The International Diving-Accident-Reporting System is being developed at the National Association of Underwater Swimmers headquarters in California. This is an effort of National Association of Underwater Instructors.

The Directory of Worldwide Shore-Based Hyperbaric Chambers enables one to locate a treatment facility nearest to the site where the accident occurred.

The Diver Equipment Information Center at Battelle in Columbus, Ohio, is concerned with all aspects of equipment: equipment available, its characteristics, where and how to procure it.

The Decompression Sickness Central Registry, at Newcastle, England, was started in 1964 as a center for storing, assessing and classifying data collected from a number of civil engineering contractors involved in the use of compressed air for the construction of tunnels and caissons.

Here at SMRL we have underway the Longitudinal Health Study of USN submarine and diving personnel. This is a long-term study following a group of divers and submariners to see what their characteristics are now and to see how they may change over a period of years.

For this workshop we have tried to select a cross section of data banks which are pertinent to our field and which represent different types of effort. We have also selected a group of people who have expertise in the theories of computer usage and data banking, and a group of people who are experts in using these banks.

B. INTERNATIONAL DECOMPRESSION DATA BANK: RUSSELL PETERSON, PH.D.

The aspects of our data bank which I would like to discuss are: (1) the purposes of starting a data bank; (2) what we hope to achieve with it; and (3) where we are now and our plans for the immediate future.

In starting a data bank we made some assumptions. One was that a large body of recorded decompression data would facilitate the testing of decompression models and pragmatic decompression schemes, and provide a means to evaluate the variable parameters of models, and also, that it would make available tested decompression schedules which would be used by the diving community. So, the aims of the International Decompression Data Bank were to make available to the diving community a reliable information service which would provide an open central repository of validated decompression data on men and animals.

We hope to provide a versatile system capable of storing a variety of data and analyzing theoretical models and calculating decompression tables. We would like to prevent loss of significant information and promote improved decompression by assisting and encouraging model analysis and table development. The plans for the accomplishment of these goals are: to overcome the problem of standardization and missing information by devising a notation system or language to use in describing altitude and pressure exposures; to develop a system for computer storage and retrieval of information which would facilitate multikey retrieval, and an automated analysis of the exposures; to develop a system for interfacing and running anyone's analysis program with the whole body of data so that it won't be necessary to transfer large amounts of information from one place to another, and to allow a person to insert his own model or own analysis scheme right into the data bank information; to establish a scientific advisory board to help determine general policies and composition of the data base; and to ensure data quality and make participation open to everyone. That includes academic groups, military groups, industrial groups, and groups with both theoretical and applied interests in decompression.

We have developed a language called PENNDEC which is designed to describe any altitude or pressure exposure. This language presents all the information required for computer processing in a strictly defined way, but with the complexity of the recorded description matched to the complexity of the dive. That is, there are several modes that can be used to record information; a simple dive can be expressed in a simple format and a more complex dive will have a more complex format to include all the information. The language allows multiple inert gases and a variety of pressure and other units, time-keeping methods which help in the readability of the information and also allow a laboratory to use pretty much the same methods in PENNDEC that it has in its recording in the past. It has been our experience that this language can easily describe a single exposure accurately.

Harvey: Having been familiar with this system when I left the University of Pennsylvania, we used the PENNDEC system to record our last air-saturation dive at NMRL. I was able to take our watch-standers, who were keeping the logs, and teach them to record in the language during the dive with really very little effort. It is very easy to use.

Libber: Evidently you're recording in your decompression data bank all validated dives.

Peterson: By validated we mean that the information is accurate. We definitely want dives with hits because unless you have hits, you can't determine whether a model is good or bad, so we do want hits. What we want though is a dive that has complete information; that is, we know what gases were breathed, when and at what depths. You can't do an analysis on a dive if you don't know what they breathed for half the dive or where they were most of the time.

Harvey: I think this question of validating the raw data before it comes in is one that every data bank faces and I am sure that all of you who deal with data banks are aware of this problem.

Peterson: This is one of the major problems - deciding how much you're going to bend - because you can get a lot of data that is almost complete but not quite; there are one or two facts that are a little hazy. Do you go ahead and do the best you can with that, or do you reject it if you aren't sure of all the bits of information? How strict should you be on the data? How much leeway is there in the analysis? Can you be hazy in one place and not really affect the analysis that you're performing?

We've gotten two large groups of dives with the CANDID data bank which we've got on tape. The other large body of data are from Ocean Systems. Here we negotiated with the group that had the data and obtained their permission to use it, and their assistance in translating the dives into PENNDEC. We have had information sent to us by different groups, industrial and military. But it's been a matter of people who have known about the bank submitting information voluntarily; other groups have been sought out and their information incorporated.

Berghage: I know the contact that was made with the Experimental Diving Unit. It was almost going to double our paperwork as far as doing it in-house, and we just didn't have the personnel or the time to record the dives twice as required. So to get those dives adequately recorded it would have required someone from the University of Pennsylvania actually to come down and transcribe them.

Peterson: What we would hope in the long run is that the groups would use PENNDEC or some system that could be easily translated into

PENNDEC to reduce the paperwork all the way across the board. Because if it's very much different, then, while your paperwork wouldn't change at all, ours would be quite massive. One of our problems has been taking raw logs and very tediously extracting all the information, usually finding out that there's information that's missing and then there's a series of exchanges between the two groups trying to fill the gaps. So, I think the first step which would make it easier for us would be to get all the information that we need on paper which should not really bother anyone because we think that this is all relevant information. Certainly there's an education problem facing us if we're to succeed and have a smoothly functioning operation.

Harvey: The International Decompression Data Bank at the University of Pennsylvania has an international advisory board, of which Dr. Ackles is a member. In Freeport, at the underwater symposium that was held there, there was a meeting of this group and they laid out certain guidelines for the Bank to follow in terms of what types of information should be recorded in it and what the Bank's efforts should be to develop liaison with the various groups.

Kuehn: What we've done with our operational unit is to encourage them to fill out their diving logs and duplicate them with carbon copies, and the carbon copies are sent in to our data bank. There's no doubling of paperwork.

Berghage: Xeroxing our logs would not be a problem but then they still have the recording problem of transcribing the logs into a usable form for the computer.

Peterson: There is a certain time period required to do that, but to date the problem is not the physical time to do it but having all the information right there in a set format so that it can be done very quickly. I want to emphasize the fact that this notational system is independent of computerizing the data. That is, it's similar to the scientific language, (ALGOL), in that it is meant as an international means of communication of a specific type of information and has an exact complete structure which can be easily computer-processed even if the dive profiles were never banked on a computer. We think that this language would be a good means of describing an exposure for a publication. The computer storage, search, and retrieval system has been developed and is in use now. It extracts and stores dive profiles described in PENNDEC and in addition to the profile certain characteristics which we call key fields, such as the depth of the dive, the bottom time, the inert gases used, and symptoms. This file can be searched to find exposures which match all the criteria listed in a search request. So, if someone were interested in a helium dive that was about an hour at a depth of 350 to 450 feet, he would submit these criteria and we would search the directory file for any dives that we have fitting these parameters. At present, a key field search can be done and these results would be sent to the inquiring investigator. He could then request some or all of the profiles listed in the key fields' summary and these would be sent to him. There's a complete tape backup system which includes three generations of tapes; a present tape, a former generation and two generations removed.

There are noncomputer files in the bank system. One is the subject file which contains all the information we have on the subjects recorded in the dive. Our subjects are listed by number only, not by name, and the present policy of the bank is not to give out subjects' names, just to identify them by number. There's an archives file which contains any experimental results from an exposure or any papers published on an exposure or a series of exposures. There's a template file which contains standard dive profiles, treatment tables, and an environmental systems file which contains information on the equipment in chambers used in any of the exposures. The scientific advisory board is a knowledgeable group of senior scientists and includes Dr. Hempleman and Dr. Ackles who are here, and Drs. Buehlmann, Chouteau, Hester, Lambertsen and Nashimoto.

The documentation for the data bank is now almost complete. We have what's called a data bank manual, and also a PENNDEC manual which is pretty much a systems manual for the language. We want to encourage submitting laboratories to use PENNDEC or some simplified version for recording their dives and we also must establish what data are desirable and the priority for its inclusion.

One suggestion for stimulation of input to the bank is that the funding agencies, which now include BuMed, ONR and NOAA, require that any dives that they fund be entered into the data bank. There is the problem of stimulation of the use of the data bank. I think the first step here is to make everyone aware of what the data bank is, what's in it, and how they can use it.

Barnard: One of the problems you mentioned was the difficulty in getting hold of the data because it is not published. This is a general problem in this field. Another point you made was the difficulty in repeating experiments. In our experience, it is very rare that anybody ever attempts to repeat an experiment exactly as it was done the first time. Another interesting problem you raised was that of updating. For example, although the Directory of Chambers is very useful as a starting point, you really need to know if it is up to date, for a shut-down chamber or one without skilled operators is useless. This is a general problem, and you will have to build in a system of updating your guidelines. One of the major difficulties is getting agreement as to what you are talking about. You should speak the same scientific language and you should understand what the other man is doing. What do you call a 'bend'? Or in the case of treatment tables, you need to know what version of the table, and what year it was published, for they keep on changing.

Another problem in trying to validate the data is whether or not you have confidence in the people who are furnishing it: whether you believe it. What arrangements do you have for validating data? Also, would you comment on the relationship between the format, i.e., the way in which you hold the data, and the types of analysis you intend to undertake? I want to give you here a ridiculous example to make my point. Let us suppose that it is discovered in the future that decompression sickness starts as a physical phenomenon but then becomes entirely biochemical and follows some complex time course, and therefore, that unless you have measured the right enzyme which we haven't yet discovered, none of the data would be very useful to you. Am I not right in thinking at the moment that underlying the way in which you built your data bank is the assumption that decompression sickness is a physical process which can be analyzed by mathematical means which we hope will produce an answer in the future?

Discussion of numerous topics followed.

Barnard: Have you got a system, or can you build a system for updating the way in which you tackle this problem? Can you see ways of persuading us to systematize the data which we have in mind? Can you get over the problem of validation in the way in which I have expressed it? And what comments have you to make about the format and its relation to the analysis?

Peterson: I'll start with the format relation to the analysis. When I started I said there were some underlying assumptions that if there were a body of data of the type that is generally collected it would be useful. And if it were found at some point that this was not the important thing in analyzing decompression studies you would knock out one of the main underpins of the whole thing. You would, of course, all immediately start measuring this hypothetical enzyme. If it were there then you would have to start from scratch.

For updating, the system itself would not have to be restructured but just the relevant information put in. On the aspect of validating the information and trusting that, we have to date worked very closely with the people from whom we have gotten information; we've had confidence in them. In many cases these were the people who actually recorded the dive and if we had problems we went directly back to them.

We hope that we have incorporated into the language a means of doing things that will be familiar to any group and that they would not have to change their own normal methods drastically to utilize the language, but that it would still be presented in such a way that another group could understand it. We allow meters and feet of sea water and clock times, minutes, and fractions of minutes. There's a statement at the beginning of the exposure which says what these units are, what the conventions are. Someone could read those and then understand what is being done throughout the dive.

Bornmann: The question of value or benefit from the data bank is one that applies to everyone who represents a data bank. You know how much this system costs you. Have you done a market survey to find out who will use it and what they are willing to give you in return for this service you're offering? It seems to me that you are at a point right now which many corporations and many product developments are facing. Is there a market for what you have to offer to the extent that you can pay your expenses?

Peterson: We are now in a state where we can present to a group what the service is, pretty much what we think they can gain from it, and we have to find a way to help distribute the cost of the bank to the people that would use it. This would require some sort of market-type survey which would take into account the number of groups that would use it, and their ability to pay for the service. However, the exact means of doing this has not been worked out.

Shilling: The standard input situation is crucial to all these systems. You either have to have a standard input or else you've got to have a staff to translate. The staff to translate gets to be fairly expensive. It is a problem that has to be faced and in some way has to be licked.

Peterson: If we in the data bank operation had to translate every single piece of paper that comes in, there's really no hope of ever accumulating a sizable data base. It would require too many people and too much time.

Kenyon: We're trying to use the word 'abstraction' rather than 'banking' because we're not clearly identifying anything but decompression sickness as our goal. We have gotten some 5,000 dives from the field, generally filled out on a standard form, and we believe it is valid data.

Ackles: Our bank of data is probably more thoroughly validated than most others because most of it was obtained in a laboratory situation where the point was to validate decompression computers. We have greatly detailed decompression profiles which not only have a time depth but have readouts of computers which are usually within a foot or two of the depths, so it's easy to cross check whether your profile is right. Also, on probably 99% of the cases we have a graphic presentation of the profiles, which is another check on the data. We've always put our material into a standard format, and the International Data Bank is able by computer translation to convert our format into their format without doing all the handwork.

Barnard: Would the computer specialists like to comment on the problems of using standard computer language or making one for yourself for a particular application like this?

Kenyon: There isn't really a difficulty in the language development in this particular case. The difficulty is in the dissemination of the data and the need for judgment of the data being used. I think that a standard language like FORTRAN makes it very viable when you go from computer to computer.

Bardin: I think the question of acceptability of dives comes in to play in two places. One is, which dive should be entered into the data bank, and the other is which dives are you going to use and which ones are going to be thrown out.

Vorosmarti: This disturbs me, the idea of people throwing data out, and saying certain data are no good. How do they know they aren't any good? If I send in a series of 50 dives and you look at the data and you say, "well, I don't believe it, we're not going to put it in", what good are the data then?

Peterson: We don't take data presented by a reputable laboratory and just arbitrarily throw it out. In general, the dives that are not included are those that have information missing.

Vorosmarti: Why can't you include dives where there is some missing information? What information are you requiring in order to put a dive in? If I say we made a 3,000-foot dive for 10 hours on the bottom and the decompression was so and so, is that a validated dive?

Peterson: What is needed for valid information are the depths, times, and gases breathed, and by whom. If we have that information, then that is sufficient. If there were hits, and indications of them and when they happened, that is also sufficient and helps to validate the dive.

Harvey: The purpose of the data bank is simply to record the best information that is available and what the limits of that information are. As long as we know that then it is up to the user whether it is attuned enough to his needs for his analysis.

Barnard: If you compare the type of laboratory dive described by Dr. Ackles with sea diving, there are important differences. Laboratory dives give full and valid records of the pressure-time course, whereas in the sea the divers may be carried vertically up and down by as much as 20 feet due to the swell. The significance of such a fluctuating pressure is not known, nor whether it might account for some of the differences seen between laboratory and sea dives.

Vorosmarti: That's the point that I was getting at. Some users might like to know how many dives were made to 300 feet using a helium-oxygen mixture, and without knowing anything else, except maybe who did them, or the bends incidence on these dives.

Hamilton: I'd like to know exactly what the access to this data bank is currently, what is proposed, how electronic access can be effected, and what the cost of this is if this has been established.

Peterson: Access now is by letter or telephone call or personal communication of some sort, asking for information. We have been talking in terms of in the future having remote computer terminals which could of course be not only intra-university but as far away as Ocean Systems or any place else, really having some sort of conversational system such as CANDID has, which would allow a group to carry on its own data manipulation. There would have to be some safeguards to the integrity of this system. Certainly getting information out would not be hampered. As for the question as to who can get at the data, the answer is anyone can. This is entirely open. One question we have is distinguishing between groups who have contributed to the bank and groups that just want to use it. We are talking in terms of members and nonmembers, making some distinction, such as that a nonmember might get limited use for a time, but then if he ever contributed any data, his limited-use status might be erased. It might be possible to have charges at different rates, so that the user would be charged at one rate, or a member would be charged at one rate, and a nonmember who really isn't contributing to the bank would have to pay heavily for this privilege.

Bardin: What we're really saying is that one of the biggest bargains around today is available and will not be so freely available possibly in the future.

C. OXFORD LINKAGE PROJECT: L. E. GILL

Medical record linkage combines separately recorded medical data concerning a particular person or group, as when hospital inpatient records are brought together with an individual's birth and death records. Record systems of which such linking is a part are currently expanding in both volume and variation of the data set used in linkage (Figure 1). Medical record linkage consists of accumulating and updating files which contain person-based longitudinal records.

In-patient records are a good example of record linkage at its simplest; the patients's record is collected upon admission, and is supplemented by a variety of sources during the inpatient stay, by the discharge details when the patient leaves the hospital, and by the clinical details when these are recorded by the clinical staff. This is called "event linkage", since it pertains to one episode in a person's medical history. Several such events may be linked to form a cumulative personal record, and this principle may apply to several hospitals so as to cover a number of types of data input.

The second and most common record linkage is "person linking", which can describe a group of persons, as in family record linkage. Spouses may be linked by indirect methods such as marriage date and the names of both partners, or by using data obtained from their marriage certificates.

The following are the uses of record linkage which have yielded the most important results: to provide an unduplicated count in measuring incidence and recurrence of chronic diseases; to provide time-based analyses on the outcome of medical care; to determine associations between particular diseases over a long period of time; to construct pedigrees of the human population to study inherited characteristics; and to study health services, including readmission patterns, morbidity and mortality.

There are two broad types of linkage which may be used, depending upon the type of data set which is available. All-or-none linkage requires a single, stable, reliable, and easily available item. Probability linkage uses a group of identifying items, all of which have variable reliability and availability.

All-or-none linkage should be used where possible because of its inherent simplicity. The records are linked if there is an exact match on a single item between the data and the main file. The item to be used usually takes the form of a unique number which is assigned to every member of the population. Such numbers are drawn from an individual's stable characteristics, such as sex, date of birth, and place of birth. These "person numbers" are on the order of 10 to 12 characters, and transposition of the characters can readily occur.

SYSTEM	UNIVERSE	SAMPLE	RECORD	FILE	UPDATING
National Population Census	Persons in Nation	10% or 100%	Cross sectional	Static	None
Hospital in-Patient Inquiry	Hospital Discharge Events	10%	Cross sectional	Cumulative	Unlinked
Hospital Activity Analysis	Hospital Discharge Events	100%	Cross sectional	Cumulative	Unlinked
Unit Medical Record	Persons entering health care	100%	Longitudinal	Cumulative	Linked (Persons)
Cancer Registry	Persons diagnosed carcinoma	100%	Longitudinal	Cumulative	Linked (Persons)
British Columbia Vital Records	Birth, death, and marriage Events	100%	Longitudinal	Cumulative	Linked (Families)
Psychiatric Case Register	Psychiatric service Events	100%	Longitudinal	Cumulative	Linked (Persons & Families)
Oxford Record Linkage Study	Hospital discharge, birth and death Events	100%	Longitudinal	Cumulative	Linked (Persons)

Figure I. Examples of Medical Information Systems

The ordering of the file and the linking step are trivial in these unique number systems. Their major disadvantage is that if the number is not accurately recorded on every document in the system to be linked, the linkage is unsuccessful and probability linkage must be used to find the unique number. If the proportion of erroneous or missing numbers is higher than several percent, then the advantages gained in using this linkage are outweighed by the clerical effort required to trace erroneous numbers.

Probability linkage must be used when there is no unique identifying feature which would make use of all-or-none linkage possible. This method is usual in a large number of systems, particularly in the health field. In probability linkage persons are identified through readily obtainable information such as sex, forename, surname, date and place of birth, or place of residence. Although the combined discriminatory power of all these items is theoretically sufficient for populations of one or two millions, in practice errors and omissions in recording make much larger data sets necessary. For small files up to 10,000 records, linkage can be performed using normal card-index methods, the probability of a correct match being quite high when based on only a few identifying items. As the number of records increases, there is a greater chance that the identifying data sets belonging to two unrelated people will be similar, and matching will have to be attempted where real differences in the data set are within the limits of error of the system. Examples of this include variations in the spelling of a surname like Homes and Holms, or the use of nicknames such as Robert and Bob.

Nearly all large name indices are based on this kind of simple identification set, and the clerical linkage step succeeds better than one might expect from the clues to be gleaned from other data in the system. Many computer-assisted methods of probability linkage have been devised, mainly for research applications, and these systems tend to have difficulty coping with erroneous and inadequate information. Yet the experiment at Oxford has proved that large-scale record linking is both accurate and economical, providing that turnround is not a prerequisite. For example, real time record linkage on a large hospital master index has not yet been shown to be accurate.

For maximum economy of both computer storage and time of execution the master file must be searched in an area where it is likely that the records would match the incoming data set. It is futile to try to match the incoming record with the whole master file. To narrow down this basic step it is necessary to order the main file. This process is based on a well-recorded item, usually the present surname, and is further subdivided according to first forename, sex, marital status, and date of birth. To alleviate spelling variation and error in the surname, one needs to use a compression algorithm, such as Soundex (Figure 2), which generates a numeric code with constant length and enhances the ordering and manipulation of the master and data files. The efficiency of the linkage completely

1. The code consists of a single alphabetic character followed by three digits.
2. The Leftmost (first) Letter of the SURNAME forms the alphabetic character of the code.
3. SUBSEQUENT characters of the SURNAME are coded according to the following table:

Letters	Code
B, F, P, V	1
C, G, J, K, Q, S, X, Z	2
D, T	3
L	4
M, N	5
R	6

4. The Letters 'A', 'E', 'I', 'O', 'U', are not coded but act as SEPARATORS. 'Y' is treated as a vowel.
5. 'W' and 'H' are ignored completely.
6. The second letter of a pair is deleted, and letters which follow letters having the same code are not coded unless the letters are separated by a SEPARATOR.

examples:

GILL	G400
SMITH	S530
STEWART	S363
STUART	S363
THOMSON	T525
THOMPSON	T512

Figure II. Soundex Encoding Routine

depends upon the compression code used, and the grouping which is thus generated. There are many such compression techniques, and studies are being carried out at Oxford on the efficacy of the various algorithms.

The Oxford Record Linkage Study uses a two-stage approach. Stage one consists of all-or-none linkage based on a compound item composed of sex, Soundex of present surname, initial letter of first forename, and date of birth. This step is similar to that used by other systems and is analogous to that used by a human clerk. This stage yields about 75% of the matches obtained.

If a pair of records partially succeeds, both enter a second stage which compares the items used in the primary stage with place of birth, street address, family, doctor, birth surname and National Health Service number. At this stage, each item is compared on both the data and master files and the degree of agreement or discrepancy estimated. Scores are calculated based on the discriminating power of each individual item, and the combined score is used to determine whether the match is accepted or not. About 20% of all matches are obtained at this stage. About one-fifth of all the secondary matches are verified clerically, without all of those around the threshold score.

Periodic changes must be made in the method to take into account growth in the file size, changes in the pattern of some of the basic items, such as rerecording a woman's file under her new married name, and a changing pattern of missing and erroneous data. The proportion of new persons entering the file decreases as the file size grows, and at some future date an asymptotic value will be reached. At Oxford, with its highly mobile and growing population, it is estimated that this value will be between 80% and 85%.

False positive matches can be eliminated by carefully adjusting the weights associated with each discriminating item, but this will enhance the percentage of missed linkages and the method is therefore capable of about 95-plus% at best. This level of linkage is quite satisfactory for most statistical purposes, but for clinical use or the retrieval of information about a rare disease, it is very close to the limit of acceptability.

The method is as good as or more efficient than manual methods which use the same data sets on large indices. There is a continuing need to research automatic methods of record linkage, and one can not assume the art has reached its final state. The initial experiments all began with small populations, but the size of some current experiments has grown to millions. The following improvements are currently being sought at Oxford: better data collection methods which include a fuller data set, and the reduction of erroneous and missing items (Figure 3); improved coding of items with automatic methods, including items such as family doctor, ward within hospital

Percentage availability of identifying information from original (retrospective) and redesigned (prospective) data collection systems

Item	method of collection	
	retrospective (1970)	prospective (mean 1971-3)
Present surname	100	100
First forename	100	100
Second forename	47	50
Maiden surname (married women)	61	91
Birth surname (both sexes)	*	93
Mother's birth surname	*	65
Date of birth	100	100
Place of birth	81	92
Date of marriage	*	32+
Address	100	100
N.H.S. number	16	20
General practitioner	92	97

* Not collected.

\+ Not fully implemented. This proportion is about 50% of married persons.

Figure III. Availability of Identifying Items

Proportions of disagreements in pairs of records derived from the same person

Item of identification	Discrepancies (%)
Surname	2
First forename	3
Second forename	1
Date of birth	
day	4
month	2
year	5
Place of birth	7
General practitioner	16 *
N.H.S. number	19

(Source: 1963-5 linkage run)

* If practice, rather than individual general practitioner is coded, this figure is 13%.

Figure IV. Discrepancies in identifying items and disease coding to the International Classification (8th edition); improved surname compression algorithm to overcome known deficiencies in the standard Soundex technique; and new file-blocking techniques to aid in the search.

A number of problems have been encountered in building the 8-year-linked file at Oxford. The surname entered into the document for immigrants has often been only a title, and only very experienced staff have been able to abstract the true surname. In some cultures the date of birth is listed as January 1st of the year in which one was born, and this reduces the discriminating power of this very valuable item. There may also be a discrepancy in the date of birth on several documents which pertain to the same person, the error ranging from as high as 5% on the year of birth to 2% on the month of birth (Figure 4). Sometimes the hospital in which the person was born is entered on the document, which lowers the discriminating power of this item, especially in indigenous populations. The Oxford area is one of high mobility and persons often change their address on subsequent entries into the master file. Though the National Health Service Number purports to be a unique number, and under suitable conditions could be used in all-or-none linkage, it is not universally available (about 15%), is complex, not quite unique, unreliable, and difficult to check automatically. Recently-married women, aliases and adopted persons also present a problem; no automatic link can be established with the last two categories.

Despite these problems, an 8-year file has been successfully linked and is now being used in a variety of research projects. The cost of such a system is low and apparently adds about 10% to the cost of collecting and preparing data records. This cost may drop still further as better identifying data sets and processing improvements are introduced, though this trend may be masked or even reversed by increasing file size and complexity. With a redesigned file-blocking technique it is estimated that a 90% primary (i.e., all-or-none) match rate could be achieved, and with use of the latest computing machines it may be possible to raise the 20,000/min match rate achieved in Oxford and Canada as high as 100,000/min.

Extension to the whole area covered by the Oxford Regional Health Authority and an increase in the number of data input types will entail considerable growth in the linked file. In 1970, after 8 years, the Oxford file contained records for 350,000 persons from a population at risk of 800,000 persons. In 1980, after 18 years, it is estimated that the file will contain the records for 825,000 persons. Extension of the file to the 2.5 million population might cause this number to rise to as high as 1.7 million persons. Our studies suggest use of a structured file system in which different record types are retained in independent subfiles and are linked by means of a population index and a pointer directory (Figure 5). All this is possible on a machine the size of a medium I.B.M. 360.

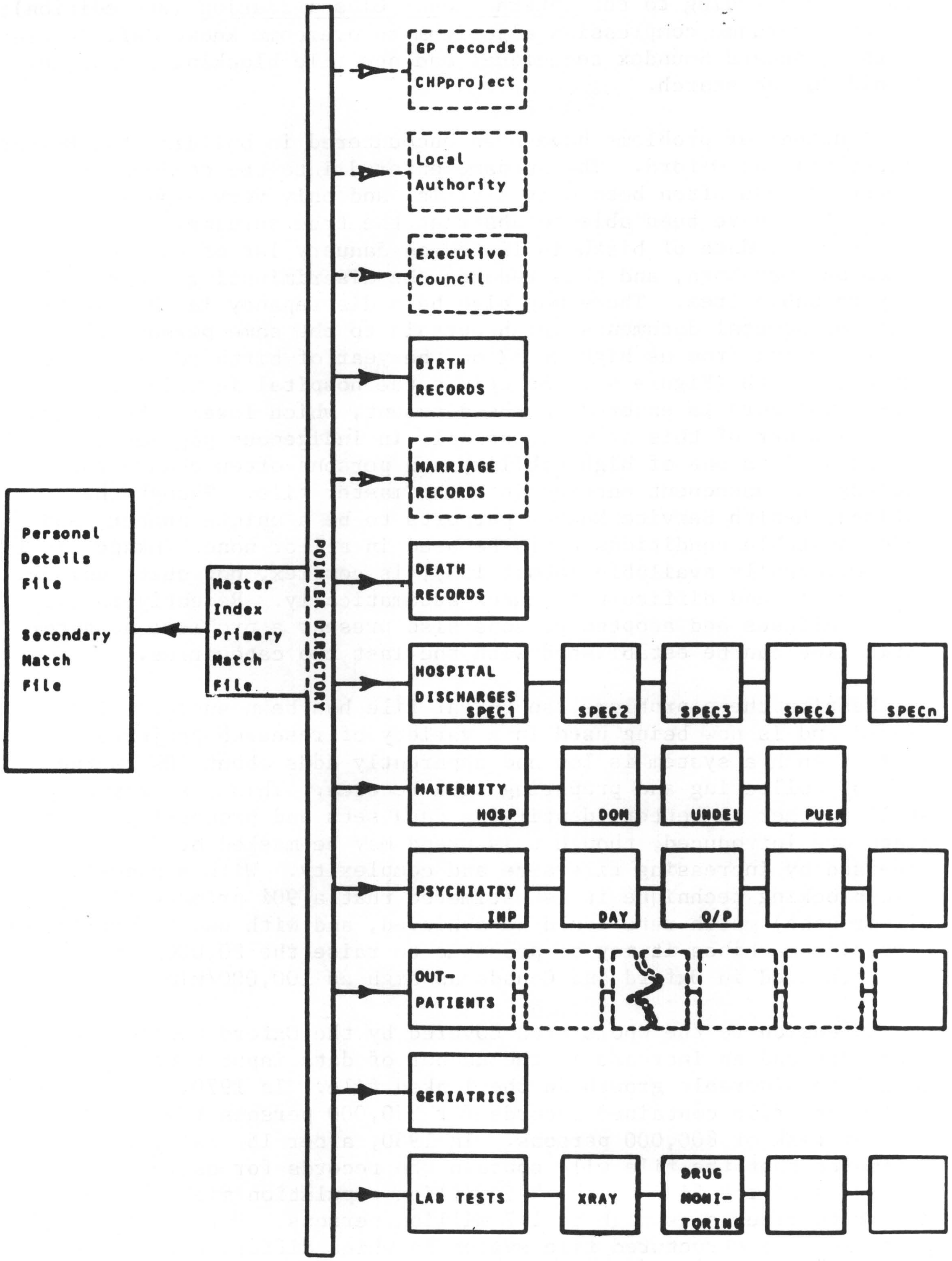


Figure V. Proposed linked file layout

D. CANDID: L. A. Kuehn

During the last twelve years there has been an extensive program of decompression research at the Defence and Civil Institute of Environmental Medicine at Toronto. Two approaches have been taken in these studies: one was to examine the physiological parameters that are changed as a consequence of decompression sickness, the other was to develop decompression computers that can safely bring man back from the depths. Since the start of this program in 1962 a large body of information and data have been collected in a very rigorous format. The human hyperbaric studies were originally performed in the chamber at the Toronto General Hospital and in 1966 we started using our own in-house chamber at DCIEM.

Three sets of data were recorded for each dive that took place. One set was that of the chamber controller's record which defined exactly what happened in the control of the chamber depth. Another was the decompression computer recorder's record which consisted of the decompression profile for the chamber as produced by a decompression computer. The last set of data is that recorded by the medical doctors and attendants monitoring the physiological state of the subjects.

In the years of diving research since 1962 we have accumulated data on approximately 1200 chamber dives and 4000 man-dives, equivalent to 25,000 man-hours of diving research information. It became obvious in August of 1969 that, to properly analyze this rigorously collected data, we would have to go to computer techniques. Mr. Stubbs, who was then Head of the Physics Group at DCIEM, asked me to set up, with the help of Ken Ackles and one of the diving officers, a decompression data bank on our PDP-9 digital computer that would be used for two purposes: first, to examine the physiological parameters that were changing in the dives, and second, to examine the performance of decompression computers. We have accomplished this task in the last four years and attained a satisfactory level of operational efficiency in the early part of 1973. We were able to analyze decompression data in the Mark 1 stage of this data bank, known as Canadian Diving Data or CANDID.

A breakdown of CANDID is shown in slide #1. The first subsection or mode is called the INPUT and serves for the transcription of our data into the bank on magnetic tape.

Slide #2 shows the format for data entry, each compilation of data being pertinent to one chamber dive or excursion and denoted as a 'file'. There are two parts to each file; the first part is called the Descriptor Block. With this block we attempted to define the parameters that were characteristic of the dive. For example, the first line in the block relates to the serial number of the file or dive in the bank, the next line relates to date of the dive, then next to starting time of dive, the next to type of excursion, the

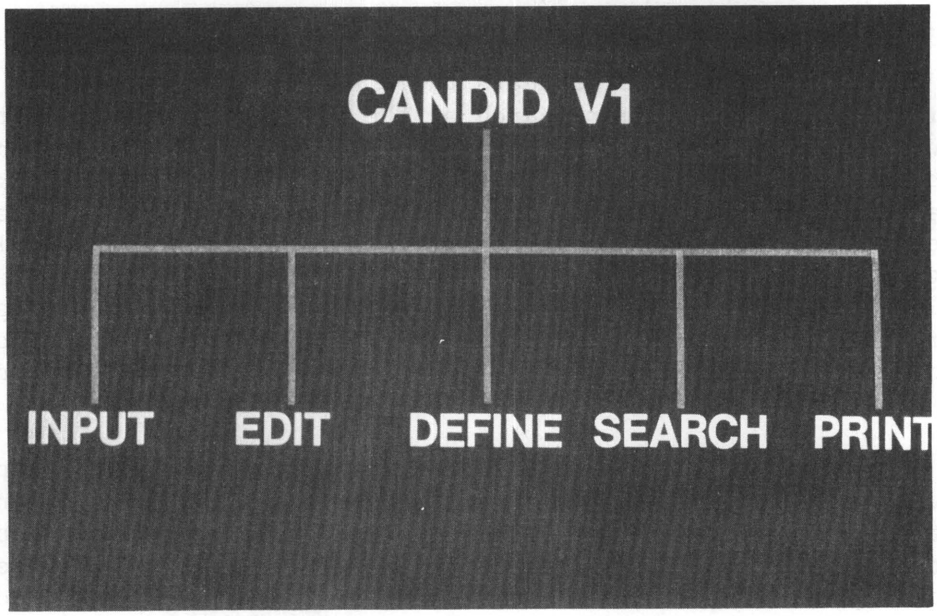
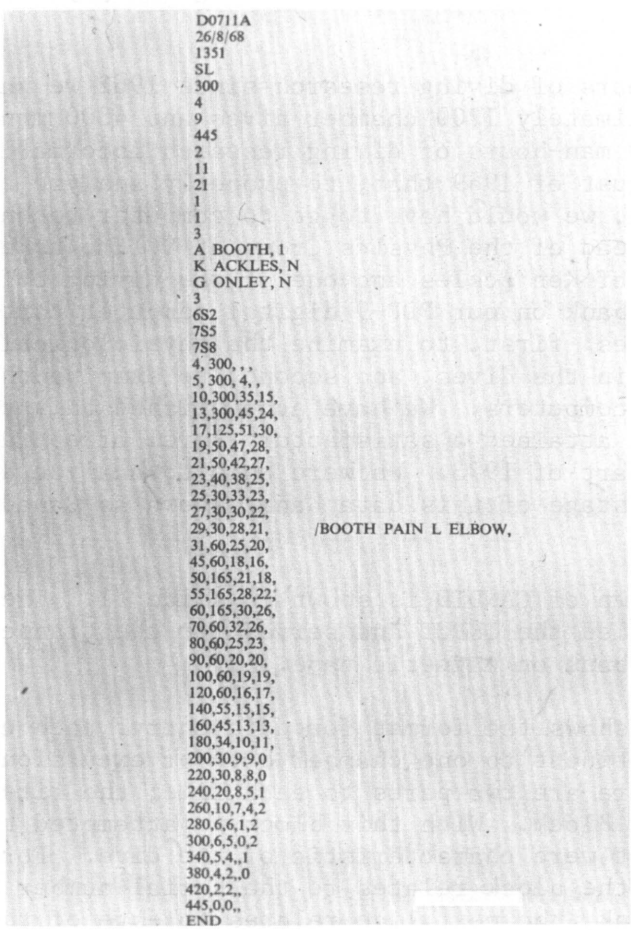


Figure 1



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D0711A
26/8/68
1351
SL
300
4
9
445
2
11
21
1
1
3
A BOOTH, 1
K ACKLES, N
G ONLEY, N
3
6S2
7S5
7S8
4, 300, , ,
5, 300, 4, ,
10,300,35,15,
13,300,45,24,
17,125,51,30,
19,50,47,28,
21,50,42,27,
23,40,38,25,
25,30,33,23,
27,30,30,22,
29,30,28,21,        /BOOTH PAIN L ELBOW,
31,60,25,20,
45,60,18,16,
50,165,21,18,
55,165,28,22;
60,165,30,26,
70,60,32,26,
80,60,25,23,
90,60,20,20,
100,60,19,19,
120,60,16,17,
140,55,15,15,
160,45,13,13,
180,34,10,11,
200,30,9,9,0
220,30,8,8,0
240,20,8,5,1
260,10,7,4,2
280,6,6,1,2
300,6,5,0,2
340,5,4,,1
380,4,2,,0
420,2,2,,
445,0,0,,
END
```

Figure 2

next to depth, the next to bottom depth, the next to bottom time, the next to decompression time, etc. Further down in the block, we have the names of the divers in the chamber or in the dive as well as some information about their decompression performance.

At the end of the Descriptor Block we have listed the serial numbers of the decompression computers used in the dive.

The next part of the file is the Profile Block, in which we have a detailed pressure-time history for the chamber during the dive. In the first sequence or line of numbers in this block we have the time of the dive, starting at time zero for the chamber compression. The next column of figures relates to the depth of the chamber at that time and successive columns to the safe-ascent depths displayed by our decompression computers.

This data bank is oriented toward the analysis of our decompression computer techniques, but in the history of diving at DCIEM we have made an extensive examination of decompression profiles based on the USN Diving Tables, the British Diving Tables and even on Brian Hills' theory of decompression. The decompression analyses permissible with the pressure-time information of each file is pertinent to models other than the Kidd-Stubbs decompression model or theory.

In addition, the Profile Block includes a method for storing physiological parameters or comments relevant to some of the decompression incidents that took place on the dive. A simple example is shown on the slide. The comment here refers to a diver, Booth, having pain in his left elbow symptomatic of a Type 1 bend. Our classification of bends is that advanced by Dr. Kidd, which I am sure many of you have seen in the literature.

Once the information has been entered into CANDID we can use the EDIT mode (see slide #1) to add or correct data or to remove data that has been found to be obsolete or not worth very much. In the DEFINE mode we have the same type of facility provided by the index of a book. For example, in reading a book you may be interested in locating certain subject matter; it is the index that provides this service. In the DEFINE mode, a CANDID user can survey the names of all the diving subjects in the bank, the type of gases used, the different experimental purposes or objectives, the serial numbers of the decompression computers used, etc. If he wants to examine any of these topics in further detail, this can be done in conversational format in the SEARCH mode by presenting CANDID with a series of conditions that are to be searched for, logically "added" together. For example, you would present to the digital computer the statement 'I want to look at the decompression performance of Diver Smith in 1968 at depths of 300 feet'. The three conditions, Smith, 1968, and 300 feet, are logically "added" together and as a consequence of the ensuing search, you are presented with the serial numbers of those files that contain this information. These files then can be further interrogated in a conversational format or be subjected to statistical analyses in the SEARCH mode. The results of these studies are made available in the PRINT mode, either on teletype output, magnetic tape, or chain printer output.

We have used CANDID in many ways in the last year. CANDID has been operational for one year in the Mark I stage and we are now embarking on the Mark 2 stage. The uses of the Mark 1 stage relate to several research objectives. First, and of paramount importance in the DCIEM Biophysics Group, there is the validation of the performance of our decompression computers. We have a long history of research and development with these computers and we are currently extending their depth and lifetime capabilities. This is an extension of the work started years ago by Dr. Kidd and Mr. Stubbs. At the same time, we are trying to evaluate the various theories of decompression that have been presented in the literature, such as that of Brian Hills, as well as the bases for the USN and British Diving Tables. We are trying to see if we can learn something from these various theories and models that can be worked into the theory of our decompression computer. The third use for CANDID has taken place in association with Dr. Ackles, and consists of an attempt to use CANDID to determine changes in any physiological parameters as a consequence of diving.

When we first set up this data bank we were not aware of all the questions or uses that we would want, but we did set it up in a way that would permit modification. Now, three or four years later, we are aware of several newly considered parameters which we would like to consider in CANDID, such as platelet counts and related biochemical changes. These parameters are now included in the design of our Mark 2 stage. The majority of the parameters under consideration relate to the physical symptoms of decompression sickness, e.g., the depth of the incident of sickness, the visible and clearly definable symptoms that a medical doctor would immediately spot. These are the parameters that we are correlating with the use of the various decompression techniques.

We are also considering several extensions of the services of CANDID. One concerns the International Decompression Data Bank to which we have released our entire store of raw file data in magnetic tape form. We have not released our analytic techniques as yet. We intend to incorporate into CANDID certain portions of the International Decompression Data Bank that are of interest to us in our studies of our decompression computer. A second extension of CANDID is the inclusion of the medical histories of all the divers referred to in CANDID. We have over 250 divers in the data bank, most of whom are still in the Canadian Forces and are accessible for information. This task will involve gathering all the medical diving records into various files in a CANDID-type format. This will permit identification of certain medical and physiological parameters which may be associated with predispositions toward decompression sickness.

To show you some of the power of this computer tool, I have in the next series of slides some preliminary presentations of certain studies that we have done. For example, before CANDID was operational, one of our professionals spent four man-months going through our massive collection of handwritten data trying to determine certain trends. Before presenting his results to the scientific community, he was asked to check his data, but obviously to ask him to do another four man-months of paper-sorting was out of the question. Such a study and consequent check could easily be done with CANDID. To elicit the answer to one question from CANDID requires approximately five minutes. The answer to this question would have required a man-week of time before CANDID was operational.

Here is slide #3 showing the results of one of the studies that has been done. It concerns the "weekend" effect, or, in other words, whether or not there is a greater tendency for divers to incur decompression sickness at the beginning of the work week than at the end of the work week. Here we have plotted the day-number of the work week. Usually we identified Monday as Day 1 but if a holiday occurred later in the week, the work week was broken and the day after the holiday was identified as Day 1. The successive work days after Day 1 are numbered in sequence. On the vertical axis we have plotted the probability of decompression sickness as manifested by two symptoms, skin itches, which we considered as a precursor of the sickness syndrome, and pain of the Type 1 variety.

The high incidence of decompression sickness seen here reflects the experimental nature of our decompression computer program in the laboratory. The use of decompression computers operationally is very successful and the decompression incidence is not as great as noted here. However, in trying to refine and improve the decompression computer profiles, it is necessary to incur a higher incidence of decompression sickness. Some operational results are included in this study. They all involve decompression governed by a surface-stationed decompression computer with a pressure-element attached to the diver via an umbilical line for exact measurement of his pressure-time history.

In slide #3, the number at the top of the bar for any work day represents the total number of diving subjects on that particular day considered in this study. The numbers in the bars represent the numbers of victims for each type of symptom. For example, on Day 1 there were 904 subjects of whom 126 reported pain during their chamber or operational hyperbaric excursion. As can be seen from the slide, there is no significant variation of either skin itches or Type 1 pain with respect to work day of the week for our diving population.

We did the same sort of study, involving months of the year instead of work days of the week (see slide #4). Again we have plotted probability of decompression sickness on the vertical axis. The months of the year are identified on the horizontal axis. We

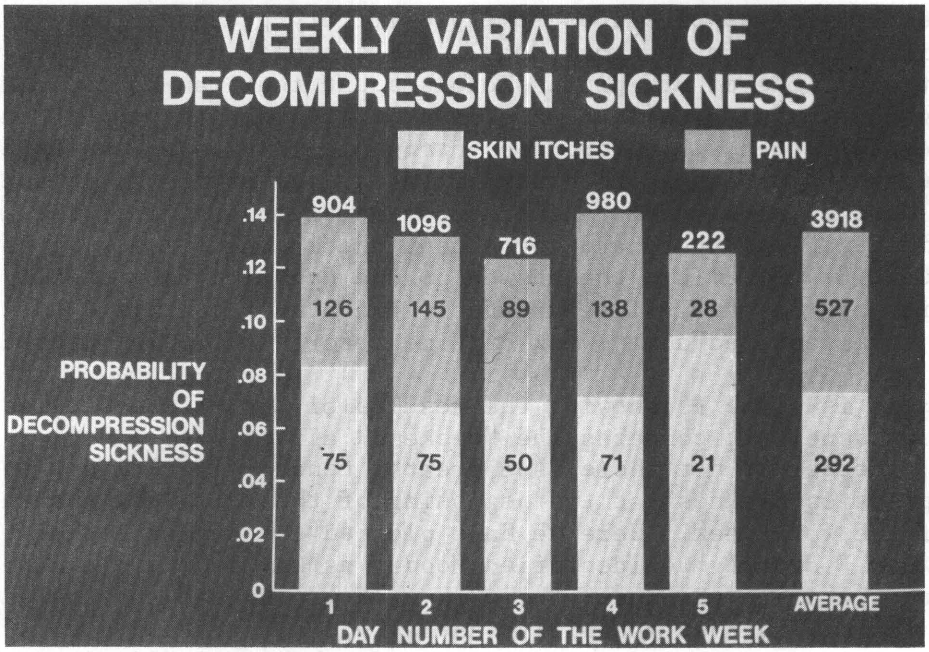


Figure 3

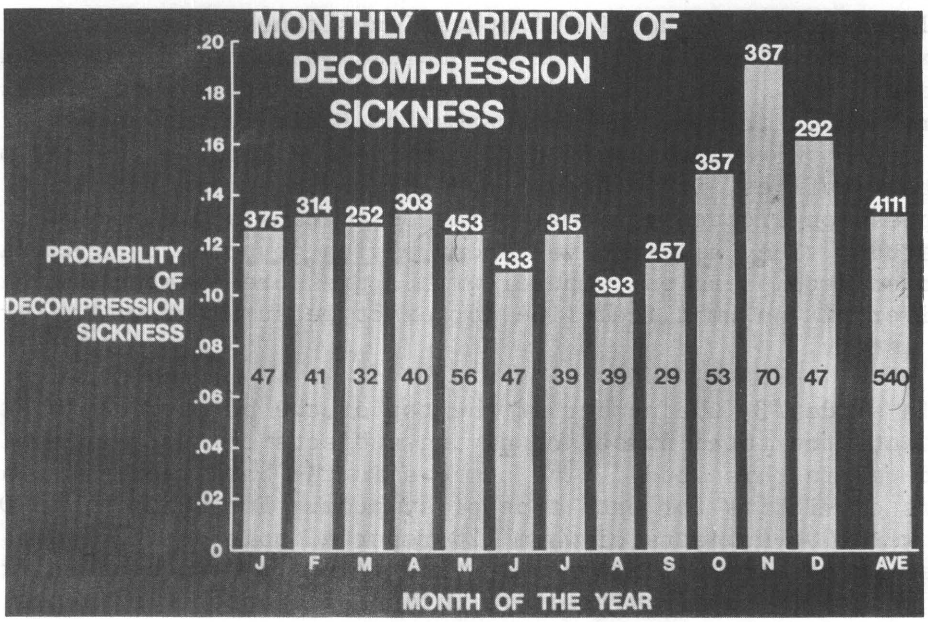


Figure 4

observed a significant rise in decompression sickness in the fall of the year but we have not yet found an explanation for it. It could reflect the higher incidence of decompression sickness observed in our inexperienced novice subjects who usually commence diving in the fall, or it could be a definite annual phenomenon pertinent to all diving subjects.

Slide #5 shows the results of a small study concerning the acclimation of our diving population. For this study, we chose to consider only those divers that are most active and for this purpose we selected only those divers who have made over 100 dives in our hyperbaric chambers. On the vertical axis we have plotted the probability of decompression sickness symptoms, either pain or skin itches, and on the horizontal axis we have plotted diving frequency expressed in numbers of dives per day. For example, the number 0.20 refers to a diving frequency of once every five days, a substantial rate of diving for our subjects. The number 0.10 refers to a diving frequency of once every ten days. We performed regression analyses on the data from our active divers and determined that although they tended to report a constant incidence of skin itches versus dive frequency, the more active divers reported less incidence of pain. This can be construed as an acclimation effect. Such a study indicates the type of analyses possible with the SEARCH mode of CANDID.

Slide #6 refers to one of the more interesting studies that was done last summer. It concerns the so-called "interval effect" which may be associated with the function of platelets in the blood of a diver during decompression sickness. On the vertical axis, we have plotted the incidence of decompression sickness at 300 feet, a depth at which we incur a high incidence of experimental decompression sickness. Operationally, our decompression computers are more successful with only 8% bends incidence at 300 feet and less than 1% at 250 feet. However, in trying to study the higher incidences of bends at 300 feet we have had to incur much higher incidences with the intent of developing a better decompression computer model so that our operational incidences of bends will fall to a more acceptable level.

On the horizontal axis we have indicated the interval of time since a diver last made a dive and we have plotted the probability of decompression sickness against this parameter. We have taken the bar on the right, that being pertinent to an interval of seven days or greater, as being indicative of the average probability of decompression sickness at this depth. Having made one dive, presumably with this probability, it is seen that diving within a few days of the first dive will be associated with a lesser probability of decompression sickness. The probability is depressed for three days before it begins to climb back up to the 'average' probability.

This phenomenon may be associated with the function of platelets in decompression sickness. Silent bubbles produced on the first dive would be surrounded by platelets which would adhere to them. Such

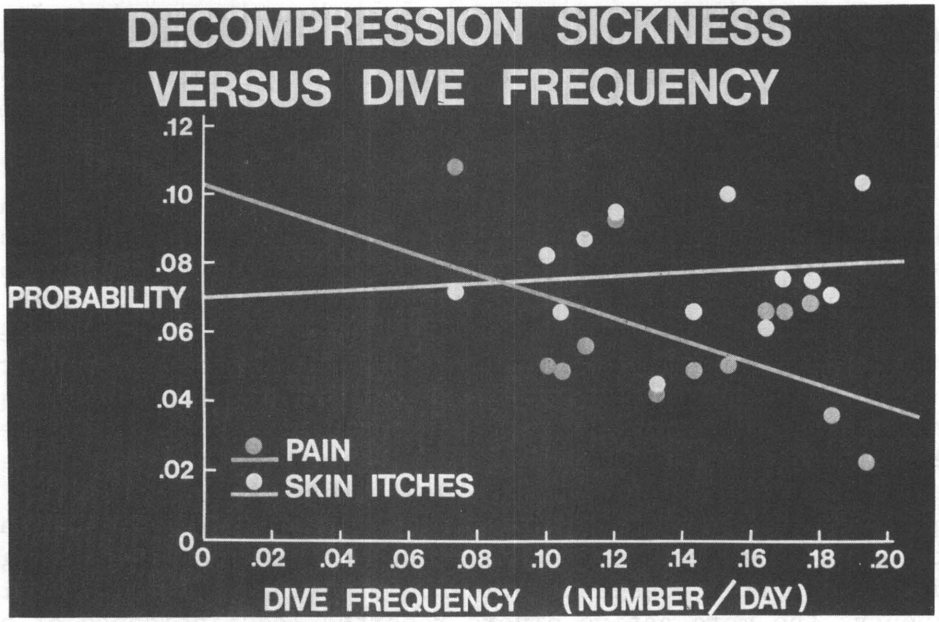


Figure 5

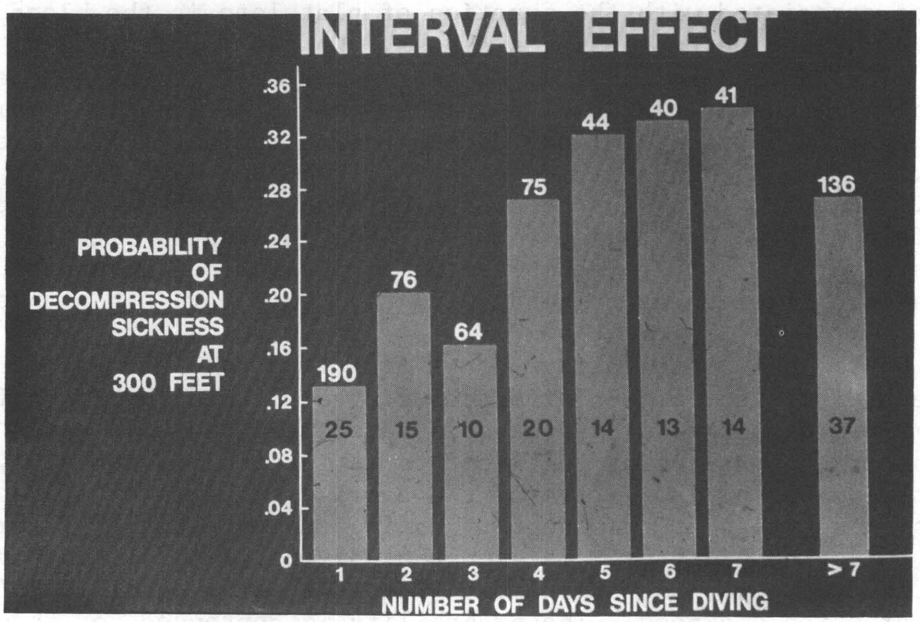


Figure 6

bubble-platelet complexes would be responsible for some of the decompression sickness incidents observed at this depth. On the second dive, made within two or three days of the first one, silent bubbles again would form but the number of 'sticky' or young platelets that could adhere to them would be far less, because of the existence of the earlier-formed bubble-platelet complexes. The incidences of decompression sickness should be and are reduced during this period. It is only when the body has had a sufficient time - over three days - to develop a larger number of young sticky platelets that the probability of decompression sickness returns to the 'average' value.

Even if the foregoing hypothesis is incorrect, we still have found a very interesting phenomenon that was entirely unpredicted. We had always assumed that a man who dives on one day without ill effect is well enough to dive again the next day. A period of 18 hours was considered long enough to dissipate the effects of the first dive. This observation indicates that the man has not returned to normal by the next day and that it may be as long as three days before he does.

Peterson: Might this not be a phenomenon due to weeding out people who are more susceptible to bends? If someone was bent on the first day, he might not have been allowed to dive on the second. Could you examine this possibility with your data and try to have some index of susceptibility for each of these days?

Kuehn: Yes. That is a novel extension to this study and one that we are considering seriously with the Mark 2 version of CANDID. I don't mean to imply that my presented hypothesis alone can explain the interval phenomenon. It is an example of the power of CANDID to detect a phenomenon that no one had predicted.

I have some comments to make further on this point. During the morning's discussion some points came up relating to recent data banks and I want to comment on these points in relation to CANDID. First of all, the point of value or benefit. The value of having this technique available to us is very important. The cost of the system to DCIEM includes part of my time as project manager on CANDID and the time spent by a numerical analyst setting it up. We have also had one and sometimes two technicians working full time for several years putting the raw data into CANDID, and then further massaging and checking it out. Of particular interest here is the assistance of Mr. Hillel Bardin of the International Decompression Data Bank. He is now asking a number of very pertinent questions of us that relate to our earliest and poorest recorded data and, because of his efforts, we are improving the usefulness of this material. Basically that covers the entire personnel requirement for CANDID, just four people plus the assistance of Mr. Bardin. In addition to this there is the requirement for the provision and maintenance of a medium-sized digital computer.

One benefit to the Defence Research Board is a tool for the refinement of performance of our decompression computers. With all of our data on tape we can quickly examine the effect of various innovations as they occur and further refine them for use in our decompression computer model. Another benefit is that we have an accurate and readily accessible record of our hyperbaric chamber performance so that the cost-effectiveness of its use can readily be determined. This task no longer requires man-months or many man-weeks; it now can be performed in a matter of hours. Another benefit of the use of CANDID is the capability to produce a detailed diving history and medical history for those subjects incurring bone necrosis or other ailments. The benefit to the diver here is that he can be given an authenticated history which can serve as evidence required for a pension or other form of reimbursement. Indeed, the knowledge that such a service is available has been very well received by our divers.

The major benefit to the use of CANDID is that it serves as an excellent usable store of the research and laboratory information pertinent to hyperbaric experimentation. There are now very few gaps in the data and that now being collected is of superb quality.

As to the point of a market analysis to determine the potential non-DCIEM users of such a system, we did submit to the newsletter, Pressure, six or seven months ago, a notice on the CANDID system, stating that it was available for use and free of charge to anyone who was interested. We had a very poor response, and that was limited to military agencies and others who were aware of the CANDID system for some time. There were not any responses from the general hyperbaric community at large.

Dr. Barnard: I think that there is a problem with the interchange of information of the sort which military people recognize as a problem of security. If you put your information into someone's data bank, lots of inferences can be made about what you are up to, simply by the data that goes in. This applies even more so to commercial organizations because as you know some decompression methods have actually been patented in the past. I wonder whether you got a poor response for that reason. A large proportion of this type of expensive research is done by the navies of the world and, certainly as far as we are concerned, we have to ask many people if we may exchange data. Consequently, responding to such a request may take months.

Dr. Kuehn: Yes, I agree. There is also the problem of user acceptance. People do not realize what can be done with these computer techniques. As Mr. Bardin has mentioned earlier, the information now offered by the International Decompression Data Bank is one of the best offers going, especially since it is free. Once people realize what is available, then I think that they will respond more quickly to it.

Another point I would like to make is that the kinds of questions we are asked can be rather difficult, for example: What is the effect of smoking on decompression sickness? Now that is one question that we never anticipated when we set CANDID up and to answer it involves going to all our divers and asking them for some kind of history of their smoking habits. That is very difficult to do. Another difficult question relates to women subjects. Are women during their menstrual cycle more susceptible to bends because of hormonal changes? This question also was not anticipated and again it would be difficult to determine the menstrual history of our women subjects. But it is certainly worth noting from here on in.

We are now branching out to provide our operational diving units with a form of CANDID that will serve to provide them with an accounting of their diving manpower and to provide us with an identification of those dives that are of a certain depth or that have certain decompression information for use in our decompression computer program.

Dr. Peterson: Now that you've lived through the development of this system and have seen some of the benefits that you can derive from it, would you do it again if you were back at the beginning?

Dr. Kuehn: Most assuredly, but we would do it better of course and we would recommend that it be done by others. If I look at such data banks only as a biophysicist interested in better designs for decompression computer models, I realize that I have a very powerful tool. We have the ability to examine decompression profiles in detail on cathode-ray tubes and to play with various decompression computer models and theories to reproduce such profiles. We have also made some interesting findings on the interval effect.

Dr. Peterson: From the analysis standpoint, are there any types of dives that you feel should not be included? For example, do you feel that it is important for the dives of your chamber attendants to be incorporated into the bank?

Dr. Kuehn: Yes, we do, because attendants sometimes get bends. Each of our dives is assigned a six-digit serial number which can be used to describe a specific family of dives, some of which pertain to the attendants. An attendant's dive is only part of a larger family of dives.

Dr. Peterson: So you do feel that even though a dive might only be to a pressure of two atmospheres for a short period of time that this information is still relevant to the individual's diving history and should be incorporated in a data bank?

Dr. Kuehn: Two points in reply. Such information is worthy of entry into a data bank if decompression time was involved, and if, in the case of no decompression, high-level oxygen breathing techniques were involved.

Dr. Barnard: Dr. Kuehn, can we clarify that? When you say 'if decompression is involved', you may dive to 30 feet, for which decompression time is required, but you may decide that you're not going to consider it. Another difficulty occurs with men who are both professional divers at work and sports divers in their spare time and you may only get information for the data bank relevant to the official dives and not of the unofficial ones. This presumably is significant.

Dr. Kuehn: Those are both good points. I shall answer the last one first. We did not keep track of the sports activities of some of the divers who may be sports enthusiasts and do dive without informing us. Our results may be affected somewhat if this practice was common.

Dr. Ackles: I don't think the DCIEM results are much affected by sports diving in Canada. Our divers do not seem to be too keen on SCUBA diving. The water is usually cold and there is only one place worth considering - Georgian Bay. I think that you would find only a small minority of divers do any diving in their spare time. It has been unofficially discouraged because of the requirements of the research on our decompression computer. If we ask a diver to dive Monday morning, we assume that he is clean in terms of decompression since we saw him the previous week in a hyperbaric chamber. But there is no official rule that the diver cannot do sports diving. I can only recollect one or two occasions when we did encounter a problem on a Monday because the diver had extensive sports diving the day before. Such incidents have involved our civilian personnel, but I have never known any of our military people to do sports diving.

Dr. Barnard: Do you take account of the aircraft journeys of the sort that one goes through to get here? Decompression to altitude can be considered as part of the history of a dive or a diver because we may be sending divers to different places by aircraft and we do have regulations to cover flying before and after diving, but I wonder if we record it?

Dr. Harvey: In doing our study of dysbaric osteonecrosis, one of the things that we were interested in was trying to trace back the diving history since the Navy has recorded them on some of our subjects. The official Navy dives get in the record but amateur dives do not. This then is a problem of trying to prove statistical relationships between some of our findings and the diving history. We simply don't have adequate means of really following a man's diving history.

Dr. Kuehn: We have looked theoretically at the problem of altitude excursions after diving, which is within the capability of our decompression computer, and we do log both off-hours and required altitude excursions of our subjects.

E. COMPUTERIZED DIVING LITERATURE FILE: LCDR THOMAS BERGHAGE, MSC, USN

When I returned to the Experimental Diving Unit (EDU) in 1970, we were confronted with a very crucial problem of literature document storage. We had five filing cabinets filled with reprints and technical reports, some of them dating back to the early 1930's. They were valuable documents in terms of historical background research, and we hated to see them lost. There was also a problem of file integrity. We had a fairly large turnover of personnel at the Experimental Diving Unit, and every time a person left, some of our documents also seemed to disappear. So, in order to maintain the integrity of these files, we had to find some alternative mode of storage. Faced with these problems of storage space and file integrity, we looked around at various storage and retrieval systems, and finally decided to adopt the standard microfiche used by the Defense Documentation Center. For retrieval purposes we went to the key-word-in-context system that is used by Chemical Abstracts and the Human Factors journal. By using the words in the document titles, we eliminated the need of going through all the documents and coding them with key words.

The literature information system at EDU is presently relatively narrow in scope in that it only deals with diving physiology and medicine. Plans for expanding it to cover all of diving are presently being developed. In addition to the storage of documents for in-house use, we also have a requirement to respond to letters of inquiry. Up until now we probably handled the situation similarly to the way you handle it. In an effort to be a little more responsive to these needs, we went back to the compressed air source books, the various underwater physiology symposia, and Dr. Shilling's abstract books. We put the references associated with these sources on a computer, an IBM 360. We presently have approximately 15,000 references. By references, I mean just the authors, the title, the source, and some additional key word descriptors that we have had to add to get around those articles where the title doesn't actually describe the material. The system is now functional, and we use it in response to requests for information. We also use it for in-house research to avoid the reinvention of the wheel. It has been very useful.

As you probably have heard, the Experimental Diving Unit is going to be moving shortly and we're going to be losing the services of the IBM 360 computer. We have recently acquired a PDP 12 mini-computer that we will be taking with us. We got the PDP 12 for two reasons: one, it is compatible with the University of Pennsylvania's PDP 12, and two, it was compatible with RNPL's PDP 8. We wrote to RNPL on the Information Exchange Program and acquired their programs for handling literature material. We had some difficulty in converting these programs, and we have had to go in with a major revision. The software package for handling literature on the PDP 12 is now just about completed.

The storage of documents can take several forms. We started out with a library type of hierarchical organization which allows a researcher to go into the files and take out, say, everything on oxygen toxicity; it's all together. It's a very nice system for browsing through the material, but it makes it very complicated when you have a document which covers several different areas. Where do you store it? You have to select one storage location and use an index for cross referencing. We've had a great deal of difficulty in that type of approach, so for the PDP system we've decided to go with a restricted vocabulary very similar to what Dr. Shilling has done, and serial filing of the microfiche.

The Navy presently has two abstracting services that they're funding. One is at the Undersea Medical Society and covers diving physiology and medicine, and the other is at Battelle and covers diver equipment and ocean engineering. We are in the process of putting together a restricted vocabulary that will cover both of these information systems, and are planning on using these two information systems as inputs to our computer data bank.

We have gone heavily into the microfilm area for two reasons: one, to avoid the loss of documents, and two, it is much less expensive. I'd like to show you the microfilm components that we've obtained so far and are presently using. Our microfilm camera was purchased from Kodak. A document received by the Experimental Diving Unit will automatically be put on microfilm-roll film. A roll of film will hold about 5,000 8 x 10 1/2 inch documents, and cost about $1.90 to have developed. The PDP 12 has three disc drives. They have a capacity to handle about 6,000 references per disc. Once we get the roll of microfilm back from being developed, a device is used to fill microfiche jackets which in turn we store in our files. We store the jackets in the rotary file and we presently have approximately 4,000 to 5,000 documents. We interrogate our information system by using key words such as oxygen toxicity. Following each interrogation, the computer indicates the number of references found. Such a general term as oxygen toxicity would probably produce several references, so one would keep adding descriptors until one had narrowed it down to maybe 10 or 12 documents. At that point, one would request a list of the documents. The requester gets a printout on our decwriter, and it gives the document's location within our microfiche files if we have it. We can go into these microfiche files, and obtain the documents needed. We can, after viewing a document, produce a hard copy. The hard copy runs about 5¢ a page. This is similar to the cost of regular Xerox. We have another device on order which should be available within the next month or two that will take the microfiche jacket and produce a duplicate microfiche copy for 4¢. With this new equipment, we will be able to send out documents on request in limited numbers for about 4¢ a copy. A microfiche holds between 70 and 90 pages on one fiche, so this will result in quite a saving. An entire report can be reproduced cheaper than a single page from the hard copy. We've had to do this because we just don't have the personnel, time, or funds to send out hard copies.

Both of the Navy-sponsored information systems retain hard copies of most of the reports they abstract. We're in the process of going out to these contractors and putting those documents on microfilm. Although the system I just described is for in-house Navy use, we eventually hope to be able to provide the service to the entire Undersea Medical Society.

The following individuals asked questions or made statements about the report by LCDR Berghage: Barnard, Bornmann, Hamilton, Harvey, Kuehn, Libber, Shilling, and Young. The most pertinent points covered were the following: The EDU is still interested in obtaining personal collections, particularly old reprints of articles by well-known authors. The data bank covers diverse areas but is strong in areas of special interest to members of the staff - it is not yet all inclusive, particularly in the non-biomedical fields. The standard size of microfiche reduction of the Defense Documentation Center is now 24 to 1. It is an in-house system but requests will be honored when possible. When all material is on the PDP 12, EDU could respond to phone calls by making a search in a matter of minutes and mailing a response the same day, but it is still too early to advertise the service.

F. HYPERBARIC EXPOSURE RECORDING SYSTEMS: LCDR W. S. MULLALY, USN

The Hyperbaric Exposure Recording System records approximately 70,000-75,000 dives per year in our data bank, which has only been in existence for three years. Unfortunately, most of these dives are within "no decompression" limits, so we don't have a broad enough base to determine the validity of any particular table; we do hope to be able to do this in the very near future.

In recent years, the Navy has had three different systems for recording dives. First, each individual diver kept a record of his own dives. When the log book was filled, which might take as long as four years if he didn't dive very often, he sent it to the Experimental Diving Unit, where it was stored in a carton and kept in the basement. Thorough accounts and analyses of the accidents reported in these log books were made, but we had no background data to enable us to judge whether the accident rate was changing, which diving procedures had greater probabilities of accident, and so forth.

About five years ago, Tom Berghage started a data processing program, which was later sent to the Naval Safety Center. The Safety Center had had a computer program for about ten years where all the data on Navy pilots and flights were stored, and we planned to do the same thing for all Navy divers, from the time they went to Diving School until they retired. We kept a good record of accidents for the years 1933-1969, and we knew that in the years 1968-1969 we had nine fatalities in Navy operational diving alone. But we didn't know whether these were nine fatalities out of 10,000, 20,000, or 30,000. It was clear that we needed a new type of recording system. We decided that the cost of having someone at the Safety Center sit down and code and then punch in all the information from the logs would be prohibitive.

The only alternative was to have the users code the information themselves. To avoid a coding system that was too complicated for the average diver to fill out, we came up with a form of six lines of information which the diver or the diving supervisor fills out (Figure 1). The form is called the combined log/report, and any individual line of the report can be expanded if need be. Line 1 of the report identifies the particular dive by recording the data, a standard Navy unit identification code, the number of divers on the dive, and the individual diver's number in the group. To avoid repetition, we are thinking of having only the first diver in a group fill out parts of this line.

Line 2 of the report includes the diver's personal data: his age, height, weight, name, and social security number, marital status, and how many dives he had made in the last 24 hours. Line 3 lists the environmental data: latitude, longitude, wave height, current, temperature, weather, visibility, and type of bottom. After line 3, the form has a series of overlays which are coded and which

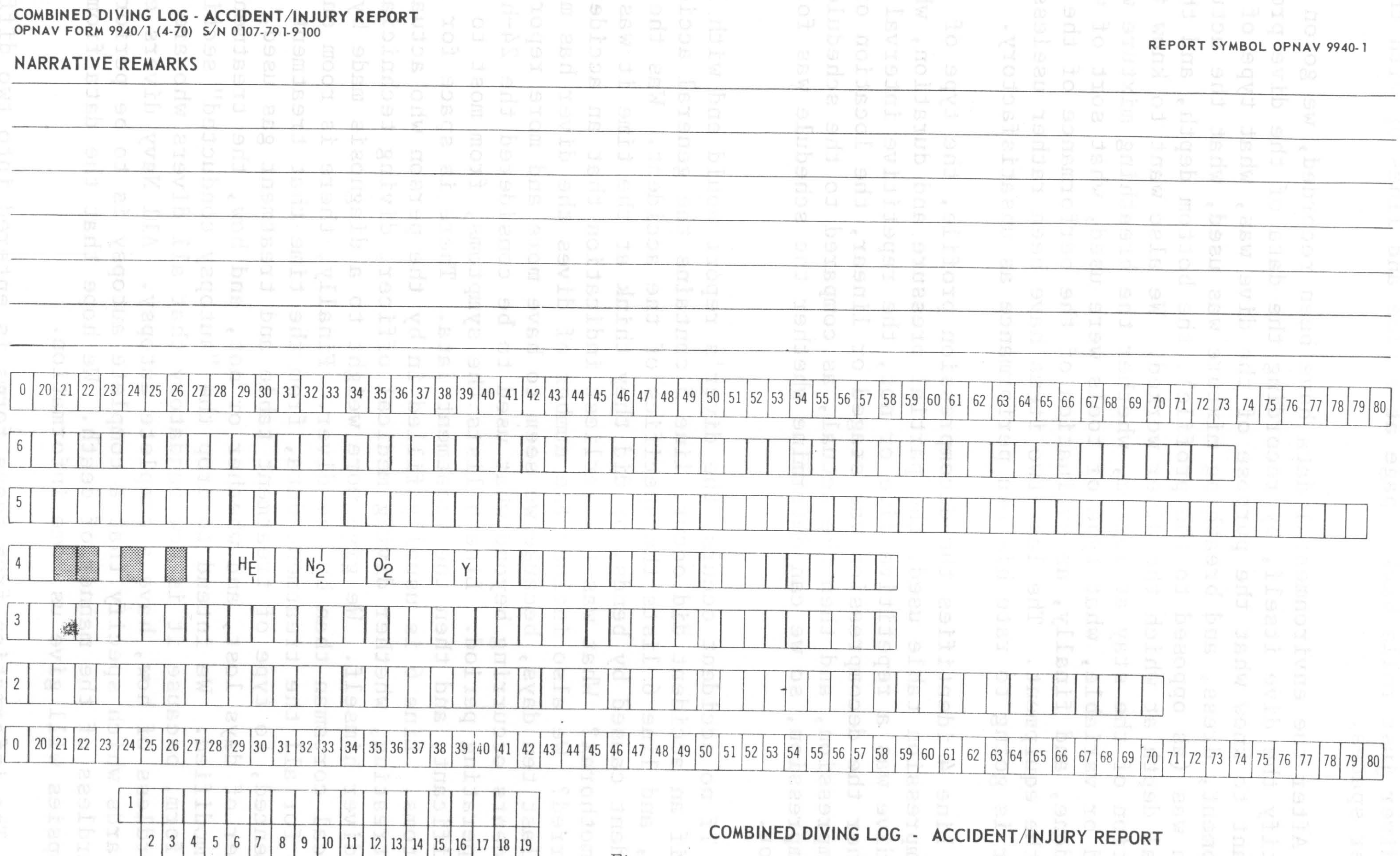

COMBINED DIVING LOG - ACCIDENT/INJURY REPORT
OPNAV FORM 9940/1 (4-70) S/N 0107-791-9100
REPORT SYMBOL OPNAV 9940-1
NARRATIVE REMARKS
HE
N2
O2
Y
COMBINED DIVING LOG - ACCIDENT/INJURY REPORT

Figure 1.

the diver just rolls back a page at a time and lines up with the proper spaces.

After the environmental data have been recorded, we go on to identify the dive itself, by recording the data of the dive profile. We want to know what the purpose of the dive was, what type of equipment, dress, and breathing mixture was used, what the actual depth was (as opposed to the profile), the bottom depth, and the actual depth at which the diver worked. We also want to know the duration of the stay at bottom, whether the breathing mixture was mixed or variable, what type of tools were used, what sort of work was done, and finally, an evaluation of the performance of the diver and the equipment. The last two items have been rather useless; no diver is going to rate his own performance as unsatisfactory.

Line 4 identifies the decompression profile, the type of decompression table used, the partial pressure and duration, whether the dive was a repetitive dive or not, the repetitive interval, whether the decompression was staged or linear, the location of the decompression, and then the actual, as compared to the scheduled, decompression, so we can determine whether the schedule was followed or not.

If no accident occurs, the diver's report would end with line 4. But if an accident did occur, line 5 contains the general accident data, and line 6 lists the specifics of the accident. Was the accident caused by bends, or did they think at the time it was pneumothorax? What was the earliest indication that an accident had occurred? We also include the number of dives the diver has made in the last ten days, because we seem to have more and more reports of accidents occurring beyond what used to be considered the 24-hour recuperating period. Line 6 lists the symptoms, from most to least significant, and then the treatment data. There is space for five symptoms. Line 6 is usually filled in by the person who actually did the treating, whether diving medical officer, diving technician, or the diver himself. We give more weight to a diagnosis made by a medical corpsman than by the diver. Finally, there is room on the form for all the treatment data, from the time that treatment commenced, to type of treatment table and treatment gas used, the number of days lost, and whether or not, and how, the treatment table was modified. We intend to drop the "autopsy conducted" section of the form, because it is now mandatory that all divers who are killed, regardless of how, have a complete autopsy. All Navy divers carry ID cards which specify that a complete autopsy is to be performed regardless of the manner of death. We hope that the data from these autopsies will give us some information.

The information from these forms is entered into two different banks at the Safety Center - the diving log, and the diving accident bank. In addition, all the diving and accident information goes into the general log. After the diver or tender has pencilled in the information on the form, the diving officer or the diving supervisor checks the information and then signs the form. This procedure cuts down on the number of errors. We also send a note to the various commands if we haven't gotten any reports from a particular diver for a year or so. Enlisting the support of the commands in this way resulted in a jump from 32,000 to 57,000 reported dives in one year. We are now getting about 75,000 reports a year, and have accumulated about 165,000 dive reports since 1970, which means a data base large enough to evaluate some of our decompression schedules.

A number of questions and comments by Ackles, Barnard, Bornmann, Hamilton, Harvey, Kuehn, Miller, and Young led to the further elucidation of the recording system.

About 10% of our dives require decompression; we classify any dive where there are no stops as a "no-compression" dive, despite the fact that they use a rate of 60 feet per minute, which is in fact a decompression schedule. Our figures include all the reports that were sent in on a Form 9940, and we are trying to generate more interest in the program so that we will eventually get reports on all the dives being conducted, whether research, experimental, or saturation. The form was not specifically designed for saturation diving, and there is some difficulty in reporting these dives on the form. We have had reports on 151 saturation dives in the past 40 months. We have not decided whether or not it is worth it to change the form or develop a program to record saturation dives more accurately.

There has been a question of the validity of data from the field, especially with the commercial dial data forms. To encourage accurate reporting, we have an amnesty provision which makes any information a diver gives on the form privileged information. Such information cannot be used against him in any court action later on. This provision is written into the OPNAV Instruction on Navy Safety program, and includes aircraft and surface ship safety as well.

If the information on the forms is not complete, we send the form back to the diver with a note asking him to complete it; this is done on a person-to-person basis, without going through the chain of command. We had some initial difficulty in getting the hierarchy to use this new computer system; it took a great deal of effort to convince them that this system was easier to use than the old narrative form of log.

The system we are using has search capabilities that allow us to say that we had so many dives with a particular table, e.g., two dives were made in the last year for 40 minutes to 120 ft., or there were 80 dives to 110 ft for 50 minutes, and one case of bends occurred. This case of bends occurred during an oxygen tolerance test. Our data base for saturation dives is still very small; in 1972, for example, only 4,000 of 57,000 reported dives were classified as decompression dives. However, by the end of this year we will have a three-year record of these dives, and we hope to be able to evaluate the tables on that basis. We also will try to pinpoint which dives actually went only to 119 ft even though a 120-ft table was used. We expect to find that most of the accidents occur when divers push the tables to the limits, because the accuracy of the depth gauges used is itself questionable. For example, a brand new one which the Navy buys is only accurate to plus or minus one percent at mid scale. On a 120-ft dive, the diver could actually be anywhere between 116-124 ft.

Many divers add their own safety factor when using the tables. They add the six feet, the distance from the pneumofathometer, or the distance from a man's chest to his feet. In fact, the diving manual specifically states that if the dive has been particularly cold, or the work particularly hard, the diver should jump to the next deeper depth and the next longer time interval on the table. Despite this, we still have a few hits. Practices like these make it essential that we have actual depths and bottom times, not just the table used.

This system also means that the diver no longer has to keep his own log book; he can call the Center at any time and get a record of all of his dives. His commanding officer or the diving master can do the same, which means that he can judge the diver's capability better than he could before. He can see that a particular diver has had an accident with HeO_2, or that he has had hits in air but is clean on O_2.

The International Decompression Data Bank at the University of Pennsylvania has developed a method for picking saturation and experimental dives out from the rest of the dives. It may be possible for the Naval Safety Center to coordinate our activities with theirs, and then to hand-record the small number of saturation dives. We are trying to work out an addendum to the present form which could be used with saturation dives. An addendum or additional sheet would save us from having to change the form, which we don't want to do, because people are just getting used to it.

We also keep all the narrative reports of accidents in a separate file, so that they can be pulled if more information than is on the accident form is needed. We also keep the rough logs on all diving accidents; there are usually only about 45 a year. But the routine reports are discarded after they have been keypunched in and checked for accuracy.

We also send out an annual report of all the statistics of diving to all the commanding officers. The officer is able to look at this report and note, for example, that at 140 ft for 30 minutes there were 80 clean dives, while there were 3 out of 15 hits at 140 ft for 40 minutes. In this way we will gradually be able to establish incidence rates, which are so important in other medical reports.

We think that coding in the field is as accurate as coding at the Safety Center would be, and certainly as accurate as a narrative report would be. Reports which are made out in the field and then sent in are often incomplete, or lack information which we think is important.

In these talks, we have heard about three different types of data banks involved in decompression. The CANDID, the Canadians' Data Bank, was designed to work with the pneumatic analog computer, and to enter the kinds of data which are of particular interest to them. The International Decompression Data Bank has emphasized unusual profiles of extreme versatility, a tremendous variety of profiles. It is useful for the wide variety of film files from experimental diving. Finally, the system we have been describing records a tremendous number of dives which follow the standard U.S. Navy tables. Our system was designed the way it is because we are primarily interested in diving safety. To do that, we have to have the big picture. The accident rate has gone down just since the inception of the Safety Center; we've only had two diving fatalities since 1969. The most recent fatality was a procedural error, not a result of a bad table. The diver was sucked into the equipment and suffered a traumatic amputation of both legs and an arm. The other diving fatality, however, was a direct result of not having a diving data bank. The diver in question had been in a serious car accident five years before, and had had a plate inserted in his head. Subsequently, he became disoriented in six feet of water in a swimming pool. In the dive which proved fatal, he lost all sense of direction, dove to the bottom in 400 feet of water and was never recovered. Had the commanding officer been able to query a data bank about this diver, the accident would never have happened.

SESSION II: SEARCH AND RETRIEVAL SOPHISTICATION

SESSION II: SEARCH AND RETRIEVAL SOPHISTICATION: COMPUTER USES AND ABUSES

A. PROBLEMS IN DATA BANKING: A. F. DEMODARAN

In setting up a data bank for almost any purpose, there are certain things one has to do right at the very beginning. You must decide just what functions this data bank is to perform as well as your aims and objectives. From these you go on to produce functional specifications of what you want the data bank to do. You look at the sort of analysis you want to be able to perform on the information that is fed it. You then address problems like the data-capture problem. How do you get this information? In what source or what form will it come? How can you actually get it into machine-readable form? How do you use differences in recording information from one place to another, one Navy to another? What is the accuracy of the readings that you actually collect? There are a number of constraints that are put upon you by the resources you have available, in terms of the data base or the data bank itself, the size of machine, the amount of money you can spend if you haven't got a machine, the sort of standards for documentation, programming standards, and the correct computing languages. Then there is the constraint of security of information from vandalism, fire, flood, misuse, etc., and taking care of the integrity of the items of information that have been correctly put into the system.

A number of other things must be considered. A logical design for your data base or your data bank itself must be mapped onto the physical devices like magnetic tapes and disc computer systems. Then you have to decide on the form of your output from the system and the priorities of time. Then there are a number of areas which touch upon the evaluation of the system: how expensive is it? does it provide a reasonable service to users? does it meet its original design aims and objectives? And then there are the much more difficult questions: questions of any additional benefits that cannot be actually translated into cash terms, the problem of cost effectiveness and cost benefit, and the question of performance of the system as a whole has to be looked at and measured.

You've got to see if you can establish a benchmark, for example, for a computer-based information system, which might very well be to look at the manual system that it will be interfaced with. Or, if there was no manual system, then you've really got to assess it in terms of the users' views of whether the system provides what is required of it.

In terms of cost, there's also a question of putting some basic accounting information into the system to show who, in fact, is using it. Even if you don't propose to charge them for it, you're accounting for the machine's usage and a system's usage doesn't necessarily imply that there will be a charging system. You must simply measure how the system is being used and by whom. If someone comes along and says that they want a load of extra information pertaining to the system, it is perfectly reasonable to point out to them that if they want that much extra information per person then the cost is going to be noticeable. Perhaps it will mean another disc drawing or maybe another two or three discs.

Now I want to go through just briefly a project that we're working on at Aberdeen and mention how a number of these different aspects have in fact affected the Aberdeen portrait. I'm doing this because a number of these issues are common to any data base information system regardless of what it is being used for. To look very briefly again at a few simple questions: the philosophy for information systems, the areas of application, stating the problems, and the question of resources. Perhaps the most difficult resources to get are good staff and computer software. We deal in data inputs from a very complex organization and we are talking about something like 5 1/2 million dollars - the current expenditure on a yearly basis. Back in Scotland, the administration of the health service is under Scottish control rather than being controlled by the National Health Service.

The Scottish scheme is roughly 235,000,000 pounds, and you can very possibly take that and double it. The biggest chunk of that is in the hospital scheme. If one is going to look at ways and means of making information systems and therefore the health service more efficient, then perhaps the thing to start looking at first would be the hospital scheme. Of that sum of money, between 79 or 81% is spent every year on the in-patient side of hospital care, which includes the hotel section of the hospital - the bed and breakfast, food, etc. In terms of sizable organization, the health service, in fact, is the largest single employer in Scotland with some 130,000 people employed.

Now if we look at the problems that face the health service, you'll see that they are remarkably similar to some of the things that you're considering at the moment. Within a particular region of the health service, for example, there is a requirement to provide the population with certain basic health care facilities, and that is very similar to the scheme that you're in so far as taking care of divers is concerned.

Our health service generates two lots of records; one lot are the doctor-created records which affect his payments - if he sees a patient or he goes out to see a patient, he chalks up figures on a piece of paper, because that's what governs his payments from the health services. Now he also creates a completely different set of records, basically recording the same kind of information which goes into making up the medical record of a patient. Now straightaway you see that he's building up two separate discrete record systems or information systems which, in a sense, is unnecessary. He's duplicating data.

Now the area that is perhaps of particular concern to you is population screening. A number of special categories of workers are at risk because of their jobs. The people who are at risk can be put under certain surveillance programs and can be scheduled for regular follow-up and call-up. There are literally hundreds of different information systems set up within the health service; psychiatric registers and psychiatric hospitals have their own systems. They are different and separate from other hospitals, as well as from the general practitioner scheme. They're separate again from group practices. Now this isn't a central way of doing things. And what is really needed is some integral scheme which would, in fact, take care of providing information to support all of these various activities from one source of information with all the data items being collected once, validated once, and updated once, instead of taking place on a number of different occasions.

What we're interested in doing is to see if we can establish an information system with data related to a defined population. In providing health care, records are produced which, though used for patient care, are also used to generate statistics as a by-product. These statistics, in fact, can also be used in simulating models.

There's also, like it or not, a cost and an accounting factor, which is a very significant and a very important thing to an accounting system which provides management with the basic information on the costs of these surgeons and also produces cost statistics at both the regional and perhaps the national level.

In addition to caring for patients there is a need for this kind of information system to support research projects, for example epidemiological research projects, and to provide information for long-term planning. Now, it is this kind of information system that we're looking at from our point of view within the Aberdeen project. As we see it, there are three levels of information required within the health service.

Information is required at the national level for planning, and statutory requirements have been promulgated to collect certain basic information. At a regional level one needs to be able to plan and control health functions. In addition to that, one has to provide facilities for research and for clinical information. In an ideal information system there is a rapid interchange of information available both upwards and downwards. So, when a doctor sees a patient at a liberal hospital or the GP scene, relative information is quickly transferred to the regional level and, if need be, the national level. That's an ideal situation. At a regional level one could be talking about very, very big files indeed, e.g., 10,000 mega-bits or 10,000 million characters. At a local level, it depends very much on the size of the hospital, and the number of people being treated as in-patients and out-patients. To provide for this sort of information one must get different computers with the characteristics that are necessary both for the national level statistical work and simulation work at a regional level for handling very big files, for data reduction and information purchasing work, and at the local level, for providing simple facilities for looking at a previous episode of a patient's record and adding a certain amount of information to it.

So, what we've done is to buy one small computer for local use and use another computer in Edinburgh for national-level work. We are writing and designing some generalized software for these machines which will be compatible with the manufacturer's data-banking system software and which is available now for the larger machines. We looked very carefully for a system tailor-made for the health services and also for a generalized system supplied by computer manufacturers.

Our problem was, of course, to find some kind of data base or data management system which would be widely accepted and fairly standard. The only system that meets those two requirements is the "Conference on Data System Language" that has its own committee to appoint a data-base management system specification. This is the specification we are using. They are basically the same people who many years ago produced the COBOL report. I think we will see over the next few years a very wide swing toward this approach. For those of you who aren't computing people, it consists very simply of a very large pigeon hole and all you do is file pieces of information into that. If you were literally using a pigeon hole system, you would have a clock that would actually say, "That piece of information goes in that pigeon hole, and the next time you want it out, come see me and I'll get it out for you". The clock, or the functions of the clock, are taken over by a program. This program is the data-base management system. The actual information within the data base is known as a jargon word. It doesn't matter who put the information in, within certain constraints like security and confidentiality.

We've heard a lot about patient identification problems and I think it was dealt with very adequately by Mr. Gill this morning, so I shall say no more about it.

In Scotland, however, we have problems with surnames. In the islands off northern Scotland there are two islands where there are only seven surnames to cover the whole island population, and they all begin with "Mac". So there are these problems of identification wherever you go. Our problem changed very suddenly after I visited a chap called Ken Bowman who is a consultant for one of the big computer companies. They are doing a scheme for King Faisal. Faisal is placing an enormous, total management information system into his brand-new hospital; money is no object. They are trying to define identification systems for use in Saudi Arabia where everybody has the same name and most of them live on the desert. They are nomads, traveling by camel and living in tents. His identification problems are worse by far than ours.

What we see going into this data base is essentially an index, which we suppose is going to crack the identification problem in some measure. We need an index to a table of contents for each person, containing symptoms, episodes of treatment, or contact with the health service. A pointer will read where that information is stored within the system.

When inquiries are made of the system, we should not regenerate just a 6-digit number to the clinician who is asking. We would, in fact, decode that information and give him back a sensible retrieval, not just the number. Various requirements could be added to this. There would have to be a table which said there is a code for a hospital in Edinburgh. This would be in the data bank. We could say then that although we don't actually have your record we know that you did, in fact, contact the hospital in Edinburgh at some previous time. Certainly, other information might be put in there, on special allergies, drug allergies in particular. This would link back to previous medical records. But beyond that, at a level for each episode of illness, there would be a short summary, probably something of the order of 2,000 characters at most per summary of information. Underneath that, there is a level of information we don't believe ought to be in which contains all the details of each particular in-patient stay. This includes things like: his fluid intake during the course of each 24-hour period, his temperature, his blood pressure, etc. These things are taken routinely. But this kind of information is inappropriate to code, put into the system, and store. So we will put a line across there and say anything below that will simply be an index linking to some more detailed information which was written up and collected from pieces of paper in the in-patient scheme.

Some things that we do see as worthwhile putting in are statements of: the time when the patient was called in, his problems, and if it was only a problem known previously. Some investigations are worth putting down, but not all: some indication of medication, the procedures which the out-patient is coming in for, and the outcome of it - information relating to the prescription of drugs, if he is on a follow-up pattern, whether we want to see him back in two weeks, four weeks, six months or a year, whether he is to return as an in-patient, out-patient, or whether we simply want to refer him back to his local doctor or general practitioner for further work. The combinations we have done so far show us that we can get most of the information we need in that area in something like between 900 and 1,200 characters of information with a bit of compression and patterning. These are examples of what we are trying to get in terms of the product.

In terms of resources, I think it is perhaps appropriate to start with staff and say very briefly that the numbers of staff working are almost irrelevant. We saw a need to have software design of a high standard. We commented on the different data-bank systems that were available. A competent design team has proven invaluable and has done things in software, linking computer systems which fit into a fraction of the size of manufacturer's software.

In assembling the team we looked for people who had viable systems design experience and data structuring experience, for example, writing computer language pilots; these people have actually proven to be invaluable because of their special skills. If we had just gone out and found a chief systems analyst who had been used to designing such forms he would never have gotten into the data-base problems. These people have designed a recording structure or structure within the data-base system which allows doctors to finally use traditional medical records for problem-based records. They can do one or the other, or a combination. They can change from one to the other without actually having to tell us. The system will itself cater to these variations, and this comes about by having people who know what the information structure is all about. We looked for people who were basically mathematicians, or perhaps physicists, who were aware of the advantages and merits of doing scheduling and cue management for the administrations - mathematicians with a very strong background of computer-systems work in the scheduling field. People like that are rather hard to find. If you want to get them commercially, they cost a great deal of money. The importance of staff cannot be overestimated.

SDC here in the States some time ago did an evaluation of their own experienced and competent computer programmers. They gave a number of their staff - I think 12 of them - a series of jobs to do. They measured how long they took to write the program, the amount of machine time they used, how long they took to do it, how much coding, and the number of characters they used. Some of these figures are very interesting indeed. Variations were 26 to 1. One person did in a week what another took 26 weeks to do. It is quite easy to see that when you get a few baffled computing people in your problem, you could end up in really dire trouble. This is one of the problems that faces any major computer project. If you get a few of these people, you might just as well pack up.

Questions about data capture have come up on a number of occasions today. The approach that we have taken is that we will always capture data. I think CDR Mullaly's approach is absolutely right, and I am convinced that if you are going to have a well-defined, efficient information system, it means you must capture data at the source where it arises. In the health services it means when the doctor sees the patient, and doctors are not always the most commendable people for doing things right, like filling in forms, for example, or making special concessions for computers. So it has been necessary to work very closely with physicians to make sure that we can offer them something, and make it worth their while to cooperate with us. This we think we have done. We will know very much better whether we have accomplished this in six month's time - when the first of our pilot schemes based on this data system ends. We think we have cracked the problem and it will be interesting to see if we have.

Actual receipt of information is also very important. A recent survey asked a hospital, which I must confess, wasn't Oxford - to carry out a spot check. They measured a certain very limited amount of registration data - the registration number, serials, page and dates - and they checked to see on the drafts they actually looked at, how many of these were in fact complete and correct. Of those looked at, 43% had some data missing, were incorrect, or just hadn't been filled in at all by the recording staff; 38% had some in which the whole form was complete, but there was some inconsistency somewhere, and only 19% were complete and consistent. Now that is the sort of thing that gives rise to very serious problems. You can get away with that sort of thing where you have medical secretaries, receptionists, clerks - human beings who will adapt in the sense of searching for information. With computer systems, you have to make sure that that kind of discrepancy just doesn't get in. The inconsistencies are the dangerous ones because they can create problems.

In terms of evaluation, the big problem seems to be with medical computing problems. People are terribly sensitive within the medical computing field because they feel that they may be putting themselves or their colleagues at risk if they do get involved in this question of evaluation. I think it is possible to do meaningful evaluation work on medical computer projects.

The evaluation that we have suggested is that three sections should be looked at. First, is the fundamental approach that has been taken right and proper in the context of the problems that the health services face? In other words, are the objectives right? If we are wrong at that point, there is no point in looking at any of the others. Secondly, the usual facilities this system provides - have their capabilities been proved at the working level? The third one is the assessment of the hardware that has been purchased, and the programs that are being written. Did we buy the right kit, the right sort, the right configuration? Are the problems as we predicted they would be? If not, why not? And from that, the next time around, one wishes to extend this - put it into a wider basis.

We haven't yet been able to convince our funding department to do the last section, the evaluation of hardware and software. They say, "No, leave that to the universities". And, maybe they're right. But we still think it ought to be done. The other area is the use of services and facilities. For that, as we see it, there must be some kind of benchmark. There must be a standard against which we are assessing a new computer system. And that benchmark can only be the manual systems that currently exist, the paper-base systems. And for that you have to establish a base line by looking at a number of different aspects of current manual systems. When you've looked at those, you perform the same measurements, in the same ways, on the computer systems. Then you stop doing comparisons. That is the only way you can get a sensible evaluation as I see it.

Now, there are a number of problems associated with that and we have to compromise to a certain extent in terms of what we do. We have decided that we will, first of all, measure actual costs in specific activities in the manual systems and the computer systems. We will ignore the set-up costs for both. In other words, we will ignore the costs of setting up a manual records department, but we will look at the cost of it before we set up functions and we will do the same with the computer systems. We will measure the cost of doing certain applications but we won't count against that the total cost of the computer, the computer building, and the staff until we have a number of different applications running. Then we will try and count the cost of all those applications against the cost of the computer and the building. We will do the same for the manual systems - the cost of the records and the storage space which then becomes a much more meaningful comparison. It is one that is causing minor ripples among people, and the heads of departments, who are concerned with the manual-records systems. On the whole, they are not wildly enthusiastic about this idea.

They were however strongly in favor of evaluating the computer product in terms of the kinds of measurements they are thinking of, of which the records department is just one. You can look at things like clerical work, availability of information, communication with other departments; how often they have to pick up pertinent X-ray information, how often they can retrieve the right record. You can then identify a number of variables and you can assess how you would measure those. A simple work study is quite adequate for most of those. You can go through and do this for a number of different departments, and when you have done it all then you have something from which you can start doing your assessment of the computer system.

There are also a number of things that have to be measured on the hardware and software sides. I won't go down this list because it is so detailed. If any of you computer people want to discuss this later, that is fine.

You can look at measures of input into the system, you can look at measures of output from the system, and you can look at this by the amount of disc space and how long these actually stay on the disc. From this you can start to assess the kind of requirements for a wide application of this system. That, very rapidly, is the project philosophy.

One of the questions this morning was, "Who will pay for the usage of a system?" If you have, for example, divers' medical records and records of their dives carried out - not just the medical records or their diving record but a combination of the two - you could start instituting things like monitoring on a routine basis, linking medical events with diving. I think you can then get to the stage where you cannot debate whether or not the system is economically viable. It probably will stand on its own right.

B. SYSTEMS APPROACH TO A DIVING DATA BANK DESIGN: DAVID M. FUERLE

The Panamex presentation outlines a general data bank architectural design approach. The emphasis of the discussion will be on the need for and flow of information and ideas within the diving community. In order to tie together the different requirements of the users of existing data banks, I will attempt to show the commonality of the various users in utilizing information for program planning, diagnostic, supportive, operational, and interpretive aids in both the applied research and operational diving environments.

Definition of Systems Approach

During the course of this presentation some new and strange words may be introduced. I am going to define some of the language in order to avoid confusion. The first principle of a systems approach is to establish a clear line of communication between individuals involved in the design. The words "systems approach" (methodology) are a good starting point. These words are relatively new to the scientific community and have different meanings to most people. For our purposes, I would like to define a system as the collection of interacting diverse human and machine elements integrated to achieve a common desired objective by manipulation and control of materials, information energy, and humans. This is the definition proposed by the Systems Science and Cybernetics Group of the Institute of Electronic and Electrical Engineers (IEEE), and which I feel is an appropriate definition for the design of a diving data bank(s). The word "approach" or methodology I will define as the following: (1) an ordering of general requirements into a real problem definition; (2) the synthesis of technology and resources in order to find possible solutions to the problem; and (3) the analysis of possible alternatives in the determination of the course of action required for problem solution. I will define a "data bank" as the repository of information and ideas which will be made easily available to the user. The "data bank" can be a book(s) or a large scale storage file (manual, semi-automated or fully automated) combined with a retrieval system.

In this broad approach to the design of a data bank, the systems design entails people dealing with technologies, hardware, software, analysis tools, and people. The organized systems approach considers the roles of people in the design, development, and operation of the system.

It is desirable to separate the role of people into several categories. There is the role of personnel in the design, development and implementation of a system. There is also the operational role of operational and user personnel once a system becomes operative. In a complex interactive system design effort such as the design of a diving data bank, it is convenient to speak of the overall activity of all personnel in terms of management functions. Slide 1 shows generalized system management functions broken down into purely management functions and systems engineering functions. The management functions address the chronological phases, scheduling, and administrative activities while the system engineering functions address the logical steps of system design and the synthesis of system subcomponents.

It is the proper blending of personnel in the organized system design approach which is essential to an effective system design. Conceptually and operationally the system design is dependent upon the interaction of the personnel in the system design. The blend of personnel here today is trying to determine, as a first step in the design effort at this workshop, what are reasonable diving data-bank inputs, constraints, decision criteria and outputs. Slide 2 represents the various operations required in the design of a system for which the required input, output, constraints, and decision criteria are first determined. It should be noted that the diagram is not meant to be chronologically ordered.

Diving Data Bank Design (Inputs/Outputs, Constraints, Decision Criteria)

At this point in the discussion I would like to address the diving data-bank design in light of the system design which we have just discussed. Consider that those present are part of a design team for such a system. This section deals with the Inputs/Outputs, Constraints, and Decision data as it affects the various potential user groups. In an attempt to define these factors the members of this workshop should ask themselves a series of questions such as those found in Slides 3 and 4. As potential users of the data bank, members here should try to write out what information they would want from a usable diving data bank. To define the diving data-bank needs, the type of questions presented above should be directed to the potential users of the data bank. If one knows the various types of queries which would constitute the input and the corresponding outputs which users would be willing to accept, then a starting point for the design would be determined.

In preparation for this discussion, I took the liberty of asking some of the potential users of an existing data bank some of these questions. The answers to the questions clearly indicated that the medical, the research, and the operational people all thought that different information was necessary and that specific accuracies on requirements and quantitative data varied significantly. The answers could explain why a large number of independent diving-related data banks have emerged over the years. A chart which lists various existing diving-related data banks is found in Slide 5. The existing data banks clearly served a unique subset of the total diving community. It is clear that the current data banks are also divided by the type of dives required to support operational diving, research laboratory diving, and medical (physiological) statistic gathering.

SYSTEM MANAGEMENT FUNCTIONS

MANAGEMENT

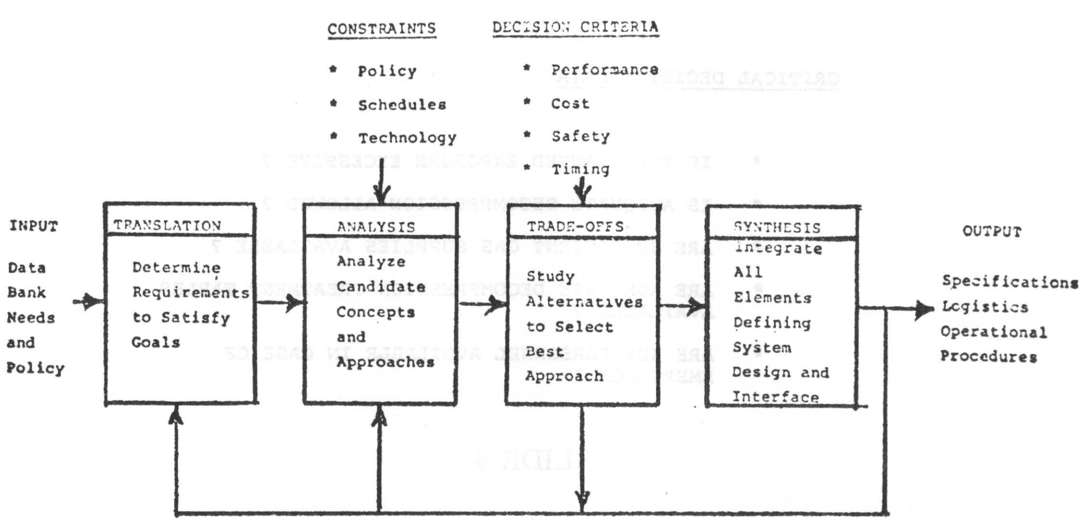
- Develop and maintain comprehensive plan
- Assign responsibilities
- Schedule key events and decisions
- Manage resources
- Assess achievement progress in all areas continuously
- Organize and plan integration and deployment phases
- Interface with other organizations

SYSTEM ENGINEERING

- Translate policy and goals to system design
- Conduct technical cost tradeoffs in concept selections
- Define interface factors to assure compatibility between major system elements
- Define back-up modes
- Plan and control system evaluation test

SLIDE 1

SYSTEM DESIGN



SLIDE 2

DATA BANK USERS' NEED TO KNOW

- * CAN I STORE MY DATA ?
- * CAN I RETRIEVE MY DATA ?
- *
- * DO DIVES WITH ······ SPECS EXIST ?
- * ARE STATISTICS ON STORED DATA AVAILABLE ?
- * WHAT ANALYSIS PROCEDURES CAN BE PERFORMED ?
- * CAN IT BE USED TO LOCATE ARTICLES ON DIVING-RELATED TOPICS ?
- *
- * CAN I OBTAIN DECISION DATA ?
- *

SLIDE 3

CRITICAL DECISION DATA

- * IS THE PLANNED EXPOSURE EXCESSIVE ?
- * IS ADEQUATE DECOMPRESSION ALLOWED ?
- * ARE SUFFICIENT GAS SUPPLIES AVAILABLE ?
- * ARE ADEQUATE DECOMPRESSION TREATMENT TABLES AVAILABLE ?
- * ARE KEY PERSONNEL AVAILABLE IN CASE OF EMERGENCY ?

SLIDE 4

EXISTING DIVING-RELATED DATA BANKS

* Integrated Diving Computation System
* U. S. Air Force School of Aerospace Medicine
* Canadian Diving Bank
* National Underwater Accident Data Center
* Human Physiology Data Bank
* Naval Safety Center
* International Diving Accident Reporting System
* Directory of Worldwide Shore-based Hyperbaric Chambers
* Diver Equipment Information Center (DEIC)
* Computerized Diving Literature File
* International Decompression Data Bank
* Bibliographic Material on Diving and Submarine Medicine
* Decompression Sickness Central Registry

SLIDE 5

In addition, answers to questions seem to indicate that the system inputs (such as environmental inputs) and system constraints were very similar for all three user groups. On the other hand, decision criteria and system output requirements were quite different. Slide 6 shows the environmental information required in undersea and aerospace applications which illustrate a single example of similarity between user groups. With this kind of information in hand the next logical step is to identify the data-bank applications which are common to the potential user groups. These applications and their implications can provide the conceptual alternatives for future analysis.

A breakdown of possible data-bank applications is found in Slide 7. This is not intended to be exhaustive, but to indicate applications common to the various user groups. The informational retrieval application provides historical diving records, operational descriptions, and current ideas and concepts to the user. The analysis application allows the user to generate statistics, diving profiles, calculate physiological constraints, optimal decompression schedules, and so forth. The inventory control application allows for operational control of required equipment, gases, laboratory supplies, diving supplies, and personnel necessary for specific diving operations. The project status and monitoring application allows for the informational support required to ensure maximum safety and soundness of decisions during the execution of research and/or operational dives. The budget control function provides the user with the ability to determine costs associated with various operations, budget accordingly, and monitor costs of operations. The quality control application provides a check on the quality and/or reliability of all information which is generated prior to actual use.

<u>General Diving Data-Bank Design</u> (Translation, Analysis, Trade-offs, Synthesis)

The next group of slides is intended to point out the considerations included in the development of a general diving data-bank architectural design, including various alternatives and classical approaches, assuming the system input and output requirements are known. As described in the previous discussion, this portion of the discussion is addressing the factors affecting the translation, analysis, tradeoffs, and synthesis of a diving data-bank as shown in Slide 2 - the Systems Design Approach.

Slide 8 summarizes some of the considerations in the architectural design of a general diving data bank.

If the answer to those questions is required by a user of the data bank, then the data bank should provide the answers. I do not pretend to know the necessary queries that the various users would want to request of a diving data bank, but I am suggesting that if the potential users would write down the types of questions they

TYPICAL ENVIRONMENTAL DIVING DATA

Chamber Dives

- Time
- Barometric Pressure
- P_{O_2}
- P_{CO_2}
- Amount of inert gases
- Temperature (dry bulb)
- Humidity
- Rate of Compression and Decompression
- Gas Contaminants
- Other Factors
  - Motion of gas in chamber (qualitative statement, e.g., still gas)
  - Vibration, Acoustic noise level
  - Lighting
  - Space/Person

Open-Sea Dives

In addition to the above data other data required:

- Undersea currents
- Temperature of Water
- Salinity
- Visibility
- Wave motion (indicated depth of subject below surface)

Aerospace

In addition to the above data other data required:

- Acceleration (3 axis)
  - linear
  - angular
- Ionizing radiation level

SLIDE 6

DATA BANK APPLICATIONS

* Information Retrieval
* Analysis
* Inventory Control
* Project Status and Monitoring
* Budget Control
* Quality Control

SLIDE 7

CONSIDERATIONS IN DEVELOPING

A GENERAL DIVING DATA BANK ARCHITECTURAL DESIGN

* Need for Information in the Diving Community
  - Program Planning
  - Diagnostics
  - Operational Support
  - Interpretive Aids
  - Analysis
* Computer Uses and Abuses
* Technical and Cost Trade-Offs
* Current Hardware/Software Data Base System Concepts
* The Group Approach
* Remote Terminal Systems
* System Parameterization
* Universal Diving Data Bank Languages

SLIDE 8

would want answered by a data bank, we would have a starting point for the systems design. After all, the purpose of the data bank is to provide the information a user needs to know in terms of individual user interests and requirements. I would hope that the next series of slides would answer the first question with regard to the need for information in the diving community.

Need for Information

On Slide 8 under "need for information in the diving community" I have listed five areas which seemed pertinent. The various data bank applications are necessary to support the operational needs in the five areas for the various user groups. Let us look at program planning, for example. In planning for a single dive or series of dives, one may desire the data bank to retrieve various kinds of information (information retrieval), analyze, and calculate various diving profiles (analysis), and generate statistics, to obtain required inventory data (inventory control) and to ensure safety and backup, (project status and monitoring); to determine the cost (budget control) of the dive in dollars and cents; and to obtain a method of checks (quality control) on the diving operation. In the diagnostics area one may wish to obtain information on previous diagnoses, perform analysis on critical parameters, examine recorded status and monitoring information, and look at quality control to determine future actions. In the operational support area one may wish to use the data bank to retrieve information in support of daily office operations required on prior dives, to process forms, and salaries, or in support of diving operations where the data bank could provide information on prior dives, calculate contingency profiles as affected by real-time changes not anticipated in the planning phase, record all pertinent information for post analysis, or call out specific actions to be performed by operational-support personnel. As an interpretive aid the data bank may be able to provide a user with all information related to a specific event, similar events, to obtain statistical relationships, or methods for checking the validity of various control parameters, and so forth. In the analysis area a data bank could provide a user with a total mathematical/statistical support package, multiple model packages, and optimization packages in support of the diving computer processing requirements of the various user groups.

A by-product of the system could be a standardization of information formats, which in turn would allow for an easier reference and method of communication between the various persons utilizing the data bank. This type of standardization would provide users with a better understanding and/or interpretation of diving-related information.

Once the necessary information which is essential to the design of the data bank has been established it becomes necessary to determine the method of storing and distributing this information to the data bank users. Data which are not changed often could be stored in the form of publications and updated periodically. For example, Slide 9 depicts the typical storage devices which are currently in use.

It is the purpose of a series of trade-off studies to determine the various advantages and disadvantages associated with the various storage and retrieval alternatives. A means of performing such studies is included later in this presentation. Access to the information may be directly from files or by calling a central library where the information is stored.

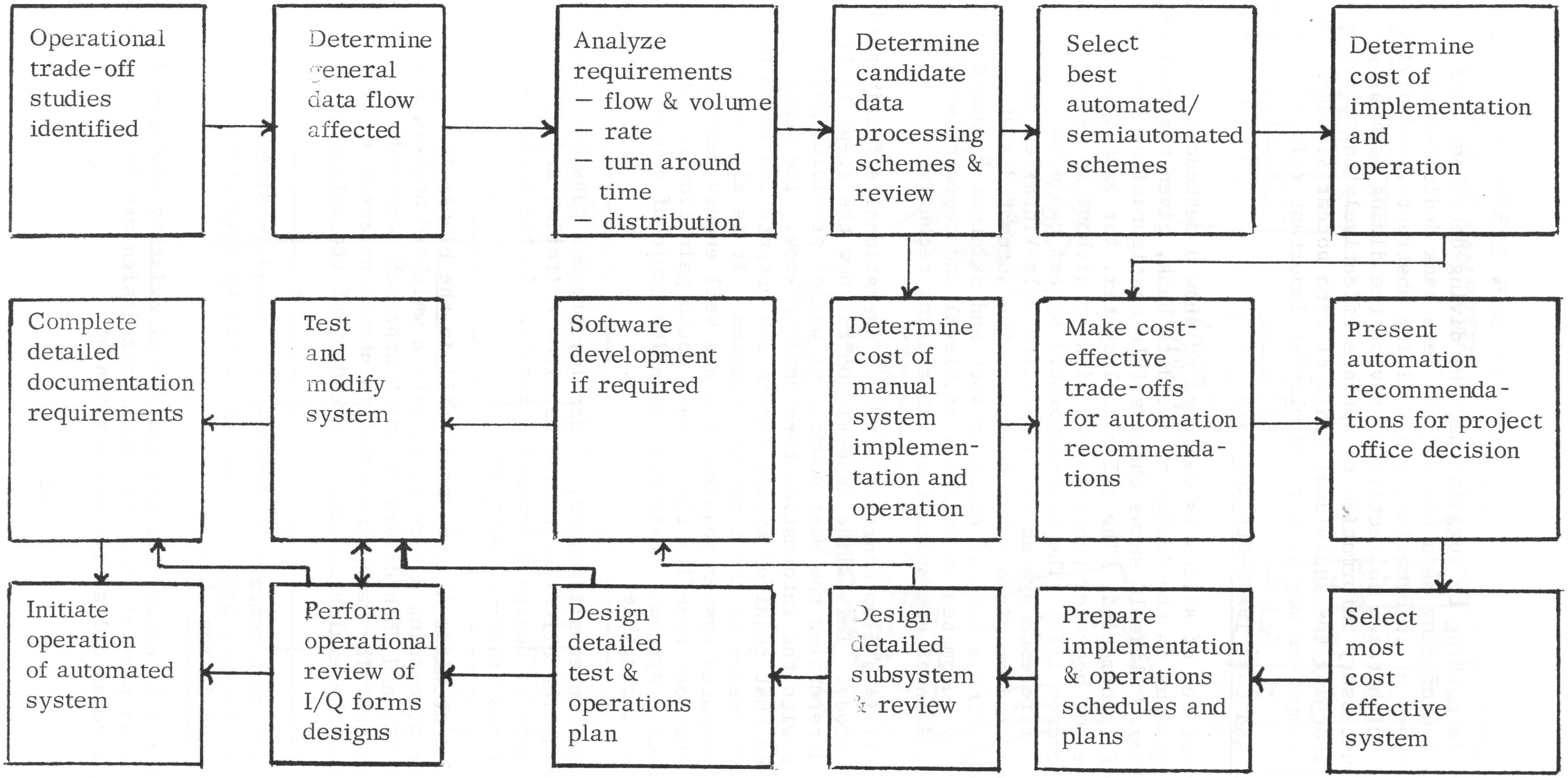
Computer Uses and Abuses

One must be very careful about catching "computer fever" and attempting to utilize computers to solve all the possible problems. As computer technology has advanced in the last 20 years we have learned that there is a tendency not only to use, but also to abuse them. It does not make sense to use computers where they do not provide cost advantages or where their use will divert valuable research time and resources into learning computers.

In many technical applications in the past, scientists and/or operational users have found that a large part of their time has been diverted into learning computer techniques. In many cases personnel have put endless energies into understanding a tool rather than using it. This is understandable to some degree, because in the technical application of computers it is necessary for people to understand what the computer printouts really mean. If the programs are written by the user there should be little doubt, but in the case of a multi-user system such as a computerized data bank, the various users must be capable of interpreting computer outputs. For this reason, it is essential to determine whether the computer is even capable of providing the various outputs to a user in a diving data-bank language which can be interpreted by all users in the same way, prior to starting a costly computerization program.

There has been nothing in the discussions presented at this workshop which even suggests that computers are related to the problems of the diving community. Computers are currently being used as a tool to collect information which, when analyzed, may provide input to the understanding of diving phenomenon, as a source of diver histories, and as statistical and model computational aids. At this point it may be advantageous to see how the current computer diving applications can be tied together with other requirements of information storage in an economical sense.

SYSTEM OPERATIONAL EFFECTIVENESS TRADE-OFF STUDIES FLOW CHART



SLIDE 11

OVERALL COMPARATIVE ADVANTAGES OF AUTOMATION ALTERNATIVES

	Time-share service	Non-time share service	Manual System
Least cost			
Provides access to all files			
Simple to use from an operational standpoint			
Flexible enough to meet exact needs			
Requires a minimum number of personnel			
Statistical & analytical information quickly available			
No additional personnel required to handle peak loads			
Large volumes handled quickly			
System is easily expanded			
Produces flawless reports			
Limits access of each file to authorized personnel only			
Specialized operational facility and personnel not required			
Provides redundancy of equipment minimizing down time			
Provides up-to-date processing equipment at negligible cost			
Provides free expertise, staff and programs for special problems			

Trade-Off Study Evaluation Criteria

SLIDE 12

SPECIFIC COST COMPARISON CHART

Cost Factors	Dollars: Auto/Semi-Auto 1 Year	Dollars: Auto/Semi-Auto 5 Year	Dollars: Manual 1 Year	Dollars: Manual 5 Year
Additional manpower for normal operations				
Additional manpower for peak loads x expected number				
New equipment				
New supplies (forms, etc.)				
Integration				
Documentation (new)				
Training				
Maintenance				
Tracking document progress x av. expected rate				
Time delays x probability of delay x expected rate				
Flexibility factor (ability to modify, add, delete, provide new reports)				
Eliminating redundancy				
Obtaining special statistical information				
Expansion with increasing volumes				
New facilities				
Totals				

SLIDE 13

Slide 14 lists the specific technical and operational information that is required for the performance of the various trade-off studies.

Current Hardware/Software Data-Base System Concepts

As you may have noted in the potential trade-off study charts, one possible approach is to utilize existing time-sharing systems; a number of national data banks currently exist which utilize these time-sharing systems. Some of these data banks are tied into information networks which are capable of accepting new systems into the network while providing the ability to make maximum use of the other systems currently in the network. A few of the national data banks which are currently tied into communications networks are listed in Slide 15.

I believe that most of you are familiar with these data banks and I will not discuss their operation with you unless someone requests that I do. The majority of these data banks provide both computer and information-retrieval capabilities to their users. The Advanced Research Projects Agency (ARPA) network, for example, allows for access to some 80 computer systems which are tied into the network.

A list of operational communications terminal-oriented networks is found in Slide 16.

Group Approach

The reason I have shown the last few slides is to emphasize the fact that there currently exists a great deal of experience and knowledge which is directly related to the technologies necessary for the development of automated data banks. This group need not be pioneers in a new technology, but can benefit from the experiences of others by utilizing existing system data concepts combined with a national network and existing data banks. I am referring here to a group approach to the data-bank design which should at least be investigated to see if such an approach would be economically possible, if not the best cost alternative available. Factors to be considered in this type of group approach are outlined in Slide 17.

System Parameterization

The most important consideration of user terminal systems which tie together multi-computer, multi-application and multi-user groups outside of costs and hardware is the development of a usable, understandable, multi-user language which in our case would be unique to the diving community. Commercial industry, in developing these languages for use, has relied heavily on a technique which is known as parameterization. This technique allows for existing operations and multi-user groups to be tied together through a

SPECIFIC DESIGN INFORMATION REQUIRED

* Size of data base
* Number of different requests to system
* Time required for response
* Special graphic requirements
* Information required to go into the system
* Number of simultaneous requests
* Number of system users
* Knowledge of the users
* Distance of users from center and from each other
* Estimated usage
* Special requirements
    - User language flexibility
    - Boolean type request logic
    - Degree of text searching/editing required
    - Report generation and formats
    - Required computer capabilities
    - Volatility of files
    - Growth of files

SLIDE 14

EXISTING NATIONAL DATA BANKS

* MEDical Literature Analysis and Retrieval System (MEDLARS)

* National Technical Information Service (NTIS)

* The Chemical Abstracts Condensates (CAC)

* Engineering Index (EI)

* Battelle Automated Search Information System (BASIS – 70)

* TOXICON

SLIDE 15

TERMINAL-ORIENTED NETWORKS

* Advanced Research Projects Agency (ARPA)

* A T & T

* DATRAN

* INFONTET

* TYMNET

* CETNET

* G E Information Services

SLIDE 16

GROUP APPROACH TO DATA BANK

* May utilize technical data and evaluations of data bank systems.

* Can make maximum use of developed interactive hardware and Informational Computer programs at a low cost.

* Can reduce costs of operations taking a user-related cost-scheduling approach.

* Obtain the necessary redundancy to assure acceptable system reliability.

* Can take advantage of ongoing information retrieval software developments.

SLIDE 17

MULTI-USER REMOTE DATA BANK SYSTEM CONSIDERATIONS

* Cost of terminals

* User-oriented English languages

* Large number of large-scale information networks

* Increase storage capabilities at decreasing costs

* Decrease postal and manual storage costs

* Current and planned communications networks (DOMSAT, etc.)

* Reliability and maintainability of equipment using solid state technology

SLIDE 18

common system while allowing for the independent and continuing use of existing formats and procedures at specific localities. Let us say, for example, that potential users (A_1, A_2, . . .A_n; B_1, B_2, . . .etc.) all operate in their normal manner. User group A, for example, could be accustomed to using the format associated with the International Data Bank, group B is accustomed to using CANDID, group C is accustomed to using the Computerized Diving Literature File, etc. Under normal operations, each of these groups is accustomed to utilizing their respective systems with corresponding file structures, operational procedures, and printed output formats. The parameterization approach would allow for the continuation of the normal procedures at the respective facilities and allow for users outside these facilities to obtain information from these facilities via a computer interface and a general user-oriented language. The user-oriented language would be accessible to the user via a remote terminal which had access to a central control computer which was tied into the same computer network as the autonomous facilities. The central control computer would maintain descriptor files which would contain information (parameters) which described the data, values, formats, and programs used by the autonomous systems (International Data Bank, CANDID, etc). Using this file, a master preprocessing program could convert data formats and requests going into and out of a user system or terminal into a generalized format. The user can then communicate with the various systems of interest by simply using the terminal-oriented common language and the general format. In response to specific requests by a user group of an unfamiliar system, the central computer facility can describe what parameters, records and information are available from the system. This information can then be retrieved and ready for use by the requesting user group or system.

<u>Remote Terminal Systems</u>

The group approach utilizes the previous technical evaluations of data-bank systems such as those evaluations expressed by the speakers this morning and yesterday as input to system design. However, the concept of multi-user remote terminal systems which utilize interactive computer-to-computer-to-terminal programming concepts is very new. This of course would be the diving-data bank approach, if we looked at the possibility of tying existing diving-data banks into a computer network which would be accessible to the diving community via remote terminals. In this approach one could utilize the experiences of the group approach related to information retrieval and communications, but special attention would be required in the development of the remote terminal interface and remote computer interface. Some of the additional considerations associated with the remote terminal/remote computer multi-user system

From an international standpoint, the terminal approach would even allow for direct access to diving information from any spot in the world if communications networks in the various continents were tied together via a carrier such as IntelSat. In fact, remote terminals could provide the means of entering new information or updating existing information directly at the source of the diving activity. In the same way information could be accessed directly at the site of the diving activity.

It is a fact that communications technology is advancing rapidly, with operational data network systems such as the ARPA network, DATRAN, TYMNET, CETNET, G. E. Information Systems, AT&T network, Western Union, designed to handle digital transmission already successful, and with systems such as DOMSAT in the United States and Canada planned within the next five years and equivalent systems planned in England, France, Germany, Sweden, Japan, and Brazil.

It is important, because of the increased data communications technology providing cheap linkages and the development of inexpensive terminals, that one consider how to utilize the opportunity to exploit the capabilities of such technological advances in lowering costs and improving services related to information flow.

The purpose of having the autonomous unit is to allow operations to proceed as usual at the unit locality. This is a significant factor, especially when large volumes of data are processed and procedures to optimize the personnel performance at the unit location have been optimized over a period of years. Conceptually, and in reality, the autonomous unit has complete control over its own operation and information. A user queries the system from a terminal connected to a central facility, which is responsible for routing the request to the appropriate autonomous unit in the proper format. If there is proprietary or other information which the autonomous system does not want released, it has the perogative of declining the external request. If the information is available, it is the function of the central facility to forward the data to the requestor terminal. I might refer back to the file descriptor of which I spoke earlier. The descriptor associated with the individual constituent may limit access to some or all (specific groups or individuals). This fact could be made known to any user who would then have the opportunity of directly contacting the constituent to plead his case.

The data-bank members may want to secure the central facility from access by anyone other than member constituents or their representatives. A common way of doing this today is by the use of a block-encrypting technique for all of the data stored at the facility. When a valid user identifies himself and the proper decrypting key is presented to the system, then and only then is access given to the data bank.

Kuehn: What you are reporting is a level of sophistication that I think is even beyond what the International Data Bank is hoping to achieve. Wouldn't this be a very expensive proposition for the constituent laboratories to set up?

Fuerle: I am suggesting here that one of the big expenses that the International Data Bank faces is the cost of collecting, converting, and disseminating information from the various constituent laboratories. I am saying, for instance, that if information presented as part of the medical system requirements, as described in earlier talks, were to be added to the International Data Bank files--let us say that the information was just stored in some master storage device--it would be more expensive to have someone key enter the data and then key update the storage constantly than it would be to allow for direct access to the information on a magnetic storage device. I am assuming here that there would be a duplication of effort as the data are also edited and updated at the medical system's facility. On the other hand, the cost of a one-time conversion program would be quite small. I might add that I am not recommending that any approach should be assumed as correct at this time. The purpose of the previous slides was to provide a methodology for making the various trade-offs between the alternative possibilities acceptable to the diving community. I have emphasized the terminal-oriented approach because I think the cost of utilizing such a system may prove small over the long run. This is true particularly when large volumes of data are involved. The investment made to date in the existing facilities and the inexpensive costs of communications when compared to labor and time tend to indicate that a federated approach to make existing facilities available to the diving community without undue modification costs should be examined.

Harvey: It is indeed a problem where there is a lack of consistency in the format of any one laboratory, and one investigator records one way and one another. You have to be awfully consistent because machines are awfully dumb. You are saying that if each laboratory has its unique format, then you can interface them through this technique just as they are attempting to do through the DCIEM tape to enter data into the International Data Bank. So, I think the system you are talking about avoids the double key-punching problem and all the rest, in that the original recording would be automatically converted.

Fuerle: Also different capabilities are allowed for at the different laboratories by this approach. The parametric descriptors would describe what files and/or data the different user facilities have, what the respective systems can do, what their inputs and outputs are.

Harvey: I think what you are also implying is that if the user is going to use the data bank, he can save in time and efficiency if he sets up a consistent format of his own, and goes through the one-time process of setting up an interface and then continues to use it. Let me add at this time that the International Data Bank's experience and excellent approach in developing the PENNDEC system to encode and process exposure profiles should be considered in developing any future user-oriented languages. The details of design associated with developing a universal diving-data bank language can be discussed later if the approach proves to be economically feasible. Many problems need to be addressed in approaching any language design.

Barnard: Ah, yes, I think we probably have accumulated a very large number of problems already, and if we don't try to produce conclusions which won't necessarily be solutions, but will point toward solutions tomorrow, we will get through.

C. INTEGRATED DIVING COMPUTATION SYSTEM: R. W. HAMILTON, JR., PH.D.

In looking around this room it seems to me that there are more bankers than there are depositors and withdrawers in this business. In fact, the laboratory in Tarrytown has three data banks for one laboratory, so right away we outnumber ourselves. What I would like to do is tell you what these data banks are and then let Dave Kenyon tell you about a couple of them, and then I would like to come back and discuss situations that relate to the use of these resources.

We have three data banks. The first relates to altitude and consists simply of a collection of 2,500 similar exposures to 37,000-feet simulated altitude that were done by the air arm of the Royal Navy. These decompressions and the resulting cases of decompression sickness were collated and stored on magnetic tape under a NASA contract, but funds were not available to complete the analysis (Kenyon et al. 1972).

We have another data bank which - as a data bank - hasn't worked well. The name was originally the "Integrated Diving System", but this is a confusing term so we stuck the word "computation" in the middle of it, making "Integrated Diving Computation System", or IDCS. This is a program which Ocean Systems developed largely under Heinz Schreiner and about which Dave Kenyon will talk in a moment.

Our third data bank is a very simple - and almost simple-minded - partly manual system that has worked superbly. There are other people in this room who were involved in this. Jim Miller sponsored it, Peter Edel worked on it as a consultant, and the experimental work was performed at Union Carbide in conjunction with the NSMRL (Naval Submarine Medical Research Laboratory). It is the project we refer to as NOAA OPS (Hamilton et al. 1973).

D. J. Kenyon: My former affiliates, Ocean Systems, Inc., and Union Carbide Corporation, and our new organization, Tarrytown Laboratories, Ltd., have been and are very interested in decompression data. We want to find clues with the data on how to solve a major problem of diving. I am referring to the prevention of decompression sickness. Now as a commercial enterprise we have to keep a jaundiced eye on costs, and the Integrated Diving Computation System was designed with this in mind. It was the result of trying to make smaller-type programs that were done on an IBM 370 system work more efficiently.

Allow me to bring a little bit of history into this. Pat Kelley, a brilliant programmer, assisted Heinz Schreiner with the development of many of the original OSI programs to develop diving tables which led to the quite successful MARK VI commercial tables, still in use and employed by Ocean Systems for the past five years. In nearly 3,000 dives on the MARK VI tables we have logged a bends incidence of 2.8%. I would say this is close to correct, although many modifications were made in the tables by field-operations people. These are things that Dr. Workman and I have talked about before, that diving people in the field report anomalies if they see them, but they will also change the procedure, by adding more oxygen and doing things like that. There have been so many changes that we really can't say if the tables themselves are clearly defined, and the resulting data are consequently difficult to interpret. For the original data base, there were a few dozen deep laboratory dives, the 650-foot saturation dive in 1965, some Buehlmann dives, Keller's record-breaking dives in which he breathed a multitude of inert gases, and Dr. Hempleman's data, which are very good and which Dr. Schreiner regards highly. Our own laboratory dives were done through the years and we had some field experience, although this is limited because at that time the state of the art was only about three to four hundred feet. These data was brought together and put into the form of the MARK VI tables.

Briefly, I would like to describe how they went through a typical analysis. They secured the data, keypunched it, and organized it for computer analysis. Kelley would then write a suitable program for a particular analysis. This is where he would "embed" the half-times for a particular mode or model that he happened to be interested in - at the time they were using a single gas system which used a perfusion-limited model based on a Haldane approach. Next the data were analyzed with respect to inert gas partial pressures in key tissues versus depth. The construction of a matrix then began by his putting provisional figures into areas of depth versus tissues, then printing out a decompression table which followed the constraints of these particular inert gas levels, which the table was not allowed to exceed.

In testing a particular table system like the MARK VI, we often had symptoms, but we were able adequately to provide for treatment of these symptoms, and as the next step in the development we modified the matrix. The evaluation of the table showed that we could get a reasonable set of helium-oxygen diving tables out to the field.

Now, through the years we kept getting more and more analytical data, and working with the Union Carbide computer group at Tonawanda we put together what is called the IDCS, out of all the programs that Pat Kelley had written. One of the programmers who had worked on the IDCS said to me when I asked for one of those original programs, "You don't want to see those things." As I said, Pat Kelley originally wrote in Fortran. He wrote a number of small routines to suit the particular application, and he wrote them, debugged them, and ran them with no eye or attention for collecting a massive system or banking the data. The IDCS was a general-purpose program to systematize the whole situation, to make it possible to evaluate diving situations, review these situations, and then to do table development on a whole series, a whole family, a whole network of tables. Whereas Kelley wrote a new program for each change in any table, the IDCS was designed to use a single program and to compute all sorts of tables by merely changing the input data.

From the data bank point of view, the IDCS capabilities as designed were to bank the data, and the IBM 370 system (360 system at the time) was employed in storing the data in analyzed form: supersaturation values on magnetic tape files. There were five organized files. Eventually it became possible to analyze the dive data, examine this against the various parameters that are involved, and then to prepare diving decompression tables based on the experience gained from the data extraction. This, the third phase of the program, proved to be very successful. But the other two phases (data entry and data storage) proved to be so time consuming and costly that they remained relatively unused. The costs were probably not really that unreasonable. But the fact that data on several thousand dives had accumulated by that time made the project look expensive even though the cost per dive was only a few dollars.

A major difficulty with IDCS was that the banking portion could not handle partial pressures or mere profiles. Everything had to be related to inert gases. Some of you people that have done this kind of work know that this is awkward. The half-times used in the analysis program were embedded in the program, as well as the model that used the half-times. The printout of the pi values from the analysis program was oriented toward a lag of values versus dives rather than values versus depths per dive or tissue compartments. If you see only pi values you don't get continuity with what was done before in the dive, nor do you get the continuity about what the other tissues were doing. Without a clear picture of the whole dive as it was done - looking at the maximum values - it is hard to relate the pi values to the observed bends. So we needed a more clearly defined listing of the particular values that were involved. The IBM 360 and 370 systems are fine machines for accounting and bookkeeping and things like that, but it turned out to be a difficult environment for us if what we wanted to know was how many bends occurred last year. The situation began to clear up when we were commissioned by the National Oceanographic and Atmospheric Administration to review diving situations employing air for a particular problem of saturated air and nitrogen diving and excursions from that. We had used a maximum tissue compartment of 416 minutes on the IDCS, but we knew from Buehlmann's studies that he was having difficulties using a 400- and a 480-minute compartment. So we set up to analyze all the way to the 1280-minute compartment, because we wanted to extrapolate and find out what was happening. We found some data that had a higher "bending" incidence than we had found in normal diving. And this is what we were interested in. We're not really interested in how to dive; we're interested in how not to dive. (See Figure 1.)

HALFTIMES FOR NITROGEN
NOAA 1972 - 1973

COMPARTMENT NUMBERS	HALFTIME MIN.
1	5
2	10
3	20
4	40
5	80
6	120
7	160
8	200
9	240
10	320
11	480
12	640
13	720
14	1000
15	1280

Figure 1

Figure 2 shows the distribution of data we used. The best kind of data is when somebody saturates and then goes wheeling off from his base, because you get an adequate representation of the tissues as they are in the spectrum; the data to the right proved to be very good. But we also had some of our own experience (listed here as OSI) when we went really deep, 400 and 300 feet. We had a lot of narcosis problems but we didn't have any bend problems. The figure shows other sources of data - DFLVR in Germany, the U.S. Navy Experimental Diving Unit and the Naval Submarine Medical Research Laboratory, and some commercial sources. Eventually we ended up with a constraint matrix (Figure 3). There were a lot of compromises made in trying to fit this, but there were no statistics done. Our effort was to try to get these values to fit, to adjust this to reflect the values we found. In many cases, we find aberrations in the increment between 10-foot stops. The increment goes to 11 feet of seawater at one point, and then for the next ten-foot change it only increases five feet of seawater. We should probably make everything smooth; that's the way physiology wants to see it. But here we had to adjust for a set of data and that caused a lot of irregularity.

We started out with Workman's data (1965), a good idea of the experience that the U.S. Navy has had. We then tried to fit in the data which was extreme, to provide for the particular job that we were doing - bounce excursions from a saturated habitat.

We also developed ascent criteria, the basis for ascending excursions. There were really only three points we could use for this. The first one is, we can probably ascend shallower than the habitat to a point in which our M-values are equal to our pi values, and stay there. (This is what decompression tables are all about; we can go until our constraint has been reached.) The second point represents the Tektite work in surfacing from a habitat, spending a given time there and recompressing for a slower decompression with oxygen. The third represents surface decompression, such as that which Ocean Systems has used. This consists of surfacing from the 40-foot stop, then recompressing to 40 feet in the chamber for oxygen breathing and the final decompression. Although the tables allow five minutes at surface we used two-and-one-half minutes to be conservative.

Figure 4 shows the constraint curve used for computation of ascending excursions.

Gas loadings were computed by the classical equation for gas transport, and these resulted in a set of "no-decompression" limits for descending excursions and safe ascent times for ascending excursions. These were tested at Tarrytown in the NOAA OPS experiments. The overall profiles of those experiments are given in Figure 5.

All exposures were completed without decompression sickness, but a niggle in an ascending excursion suggests we are approaching the limit.

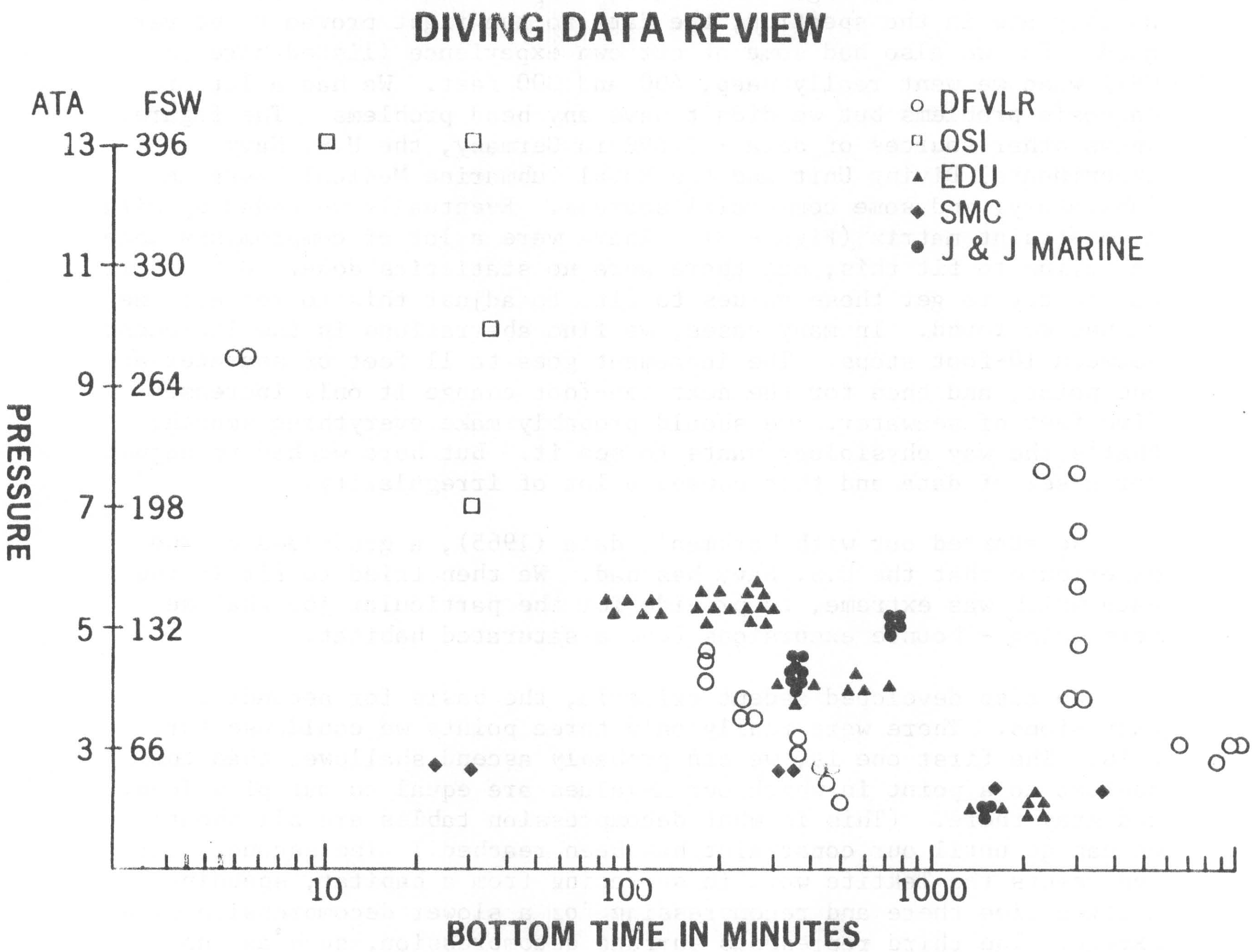


Figure 2. Time-depth display of data used in NOAA OPS

CONSTRAINT MATRIX 32/02

DEPTH FSW	M-VALUES FOR EACH COMPARTMENT WITH HALFTIME VALUES IN MIN														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	5	10	20	40	80	120	160	200	240	320	480	640	720	1000	1280
250	380	360	335	333	330	330	327	315	314	313	311	308	307	302	297
240	370	350	325	323	320	320	315	304	303	302	300	297	296	291	286
230	360	340	315	313	310	310	304	293	292	291	289	286	285	280	275
220	350	330	305	303	300	299	292	282	281	280	278	275	274	269	264
210	340	320	295	293	290	288	281	271	270	269	267	264	263	258	253
200	330	310	285	283	280	277	269	260	259	258	256	253	252	247	242
190	320	300	275	273	270	266	258	249	248	247	245	242	241	236	231
180	310	290	265	263	260	255	246	238	237	236	234	231	230	255	220
170	300	280	255	253	250	244	235	227	226	225	223	220	219	214	209
160	290	270	245	243	240	232	224	216	215	214	212	209	208	203	193
150	280	260	235	233	230	220	212	205	204	203	201	198	197	192	187
140	270	250	225	223	219	208	201	194	193	192	190	187	186	181	176
130	260	240	215	213	208	196	189	183	182	181	179	176	175	170	165
120	250	230	205	198	193	183	178	172	171	170	168	165	164	159	154
110	240	220	195	183	180	170	166	161	160	159	157	154	153	148	143
100	230	210	175	170	167	158	155	150	149	148	146	143	142	137	132
90	220	200	160	158	156	142	141	139	138	137	135	132	131	126	121
80	210	190	150	148	145	119	118	118	118	118	118	118	118	115	110
70	200	180	142	138	132	114	113	113	113	113	113	110	109	104	99
60	190	168	134	128	120	108	107	106	105	104	102	99	98	93	88
50	172	152	128	113	106	98	97	95	94	93	91	88	87	82	77
40	154	136	117	98	93	88	86	84	83	82	80	77	76	71	67
30	136	120	102	84	80	76	75	73	72	71	69	66	65	60	57
20	118	104	87	70	67	64	63	62	61	60	58	55	54	50	47
10	100	88	72	56	54	52	51	51	50	49	47	44	43	40	37

Figure 3

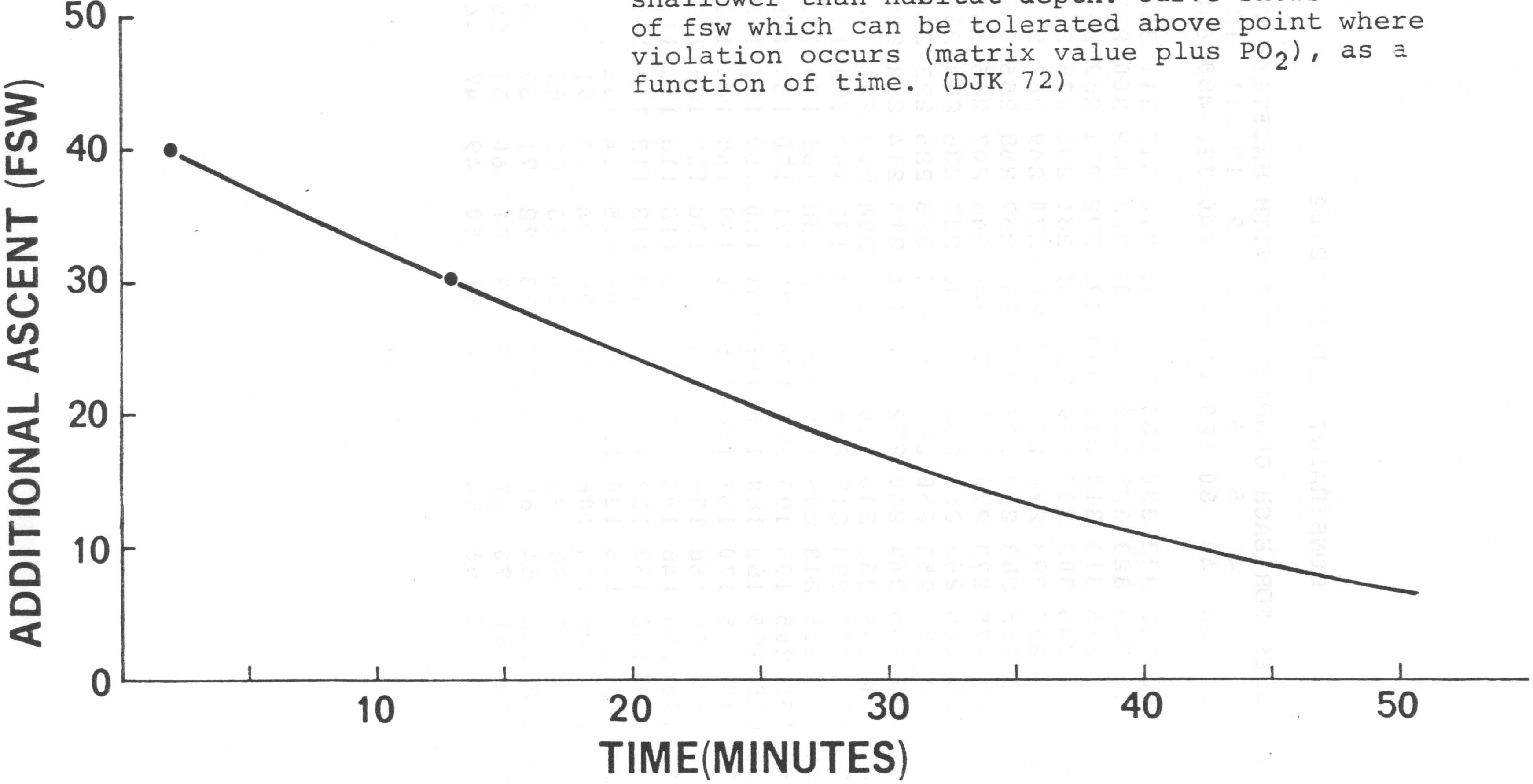


Figure 4. Ascent criteria, for ascent to depths shallower than habitat depth. Curve shows number of fsw which can be tolerated above point where violation occurs (matrix value plus PO_2), as a function of time. (DJK 72)

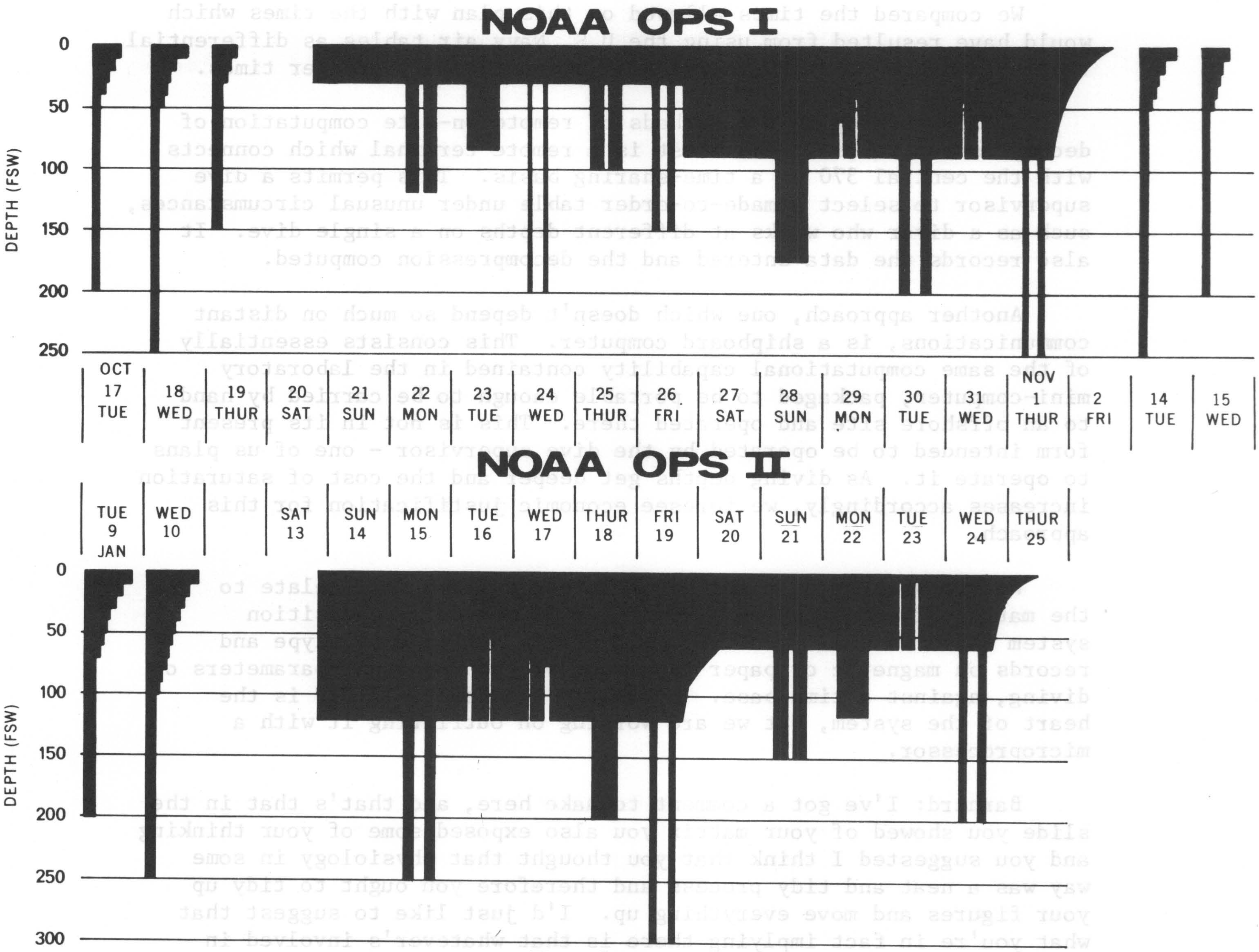

NOAA OPS I
DEPTH (FSW)
0
50
100
150
200
250
OCT 17 TUE
18 WED
19 THUR
20 SAT
21 SUN
22 MON
23 TUE
24 WED
25 THUR
26 FRI
27 SAT
28 SUN
29 MON
30 TUE
31 WED
NOV 1 THUR
2 FRI
14 TUE
15 WED
NOAA OPS II
TUE 9 JAN
WED 10
SAT 13
SUN 14
MON 15
TUE 16
WED 17
THUR 18
FRI 19
SAT 20
SUN 21
MON 22
TUE 23
WED 24
THUR 25
DEPTH (FSW)
0
50
100
150
200
250
300

Figure 5

We compared the times allowed on this plan with the times which would have resulted from using the U.S. Navy air tables as differential tables, and the NOAA OPS regime allows considerably greater times.

We are working on two methods of remote on-site computation of decompression tables. The first is a remote terminal which connects with the central 370 on a time-sharing basis. This permits a dive supervisor to select a made-to-order table under unusual circumstances, such as a diver who works at different depths on a single dive. It also records the data entered and the decompression computed.

Another approach, one which doesn't depend so much on distant communications, is a shipboard computer. This consists essentially of the same computational capability contained in the laboratory mini-computer, packaged to be portable enough to be carried by hand to an offshore site and operated there. This is not in its present form intended to be operated by the dive supervisor - one of us plans to operate it. As diving depths get deeper and the cost of saturation increases accordingly, we foresee economic justification for this approach.

We are working on a series of hardware items that relate to the matter of data banking. The first is our data-acquisition system which we call "Monitor". It prints out on a teletype and records on magnetic or paper tape many of the important parameters of diving, against a time base. Currently the Honeywell 316 is the heart of the system, but we are working on outfitting it with a microprocessor.

Barnard: I've got a comment to make here, and that's that in the slide you showed of your matrix you also exposed some of your thinking and you suggested I think that you thought that physiology in some way was a neat and tidy process and therefore you ought to tidy up your figures and move everything up. I'd just like to suggest that what you're in fact implying there is that whatever's involved in producing decompression is a linear system, without kinks in it. It may be that you have discovered that there are kinks in it and we should leave them in.

Kenyon: We don't know. We are also identifying possibilities of that type of matrix being not altogether valid. In other words, we think that the M-values change, and this possibly had its dynamic effect right there - that we were looking at it in a spectrum of time only, in the one instance of time where this particular value was.

Peterson: Can you compare or estimate the saving, if any, in terms of something concrete, like number of decompression tests or the expense of developing the table? In one case you've used a matrix derived from experimental data and in the other you've used some accepted model or a previously tried matrix for another situation. In other words, do you think you really have a saving when you derive a matrix on experimental data as you describe?

Kenyon: In many cases we just don't have something to use. We have used existing matrices - e.g., Dr. Workman's matrix - in many cases, and we have had very successful results. In the case of the Access series, in which we were saturating at 500 feet of seawater and doing bounce diving to 1,000 feet and coming back to 500, the matrix and the experience factor is zilch - there's just nothing there. There have been a number of good experiments in this area; EDU did some.

Workman: Not for saturation values. They had some excursions, but I don't think there is a whole body of data to extend M-values on down say from 500 to 1,000, do you?

Kenyon: No. Well, we did have a number of good sources. EDU did some 500-and 600-foot excursions, and we also had RNPL, who had some good data. Buehlmann does unusual dives and you get some very good data there. Keller's dives provided some, but there wasn't a matrix available.

Peterson: So the conclusion is that you wouldn't feel confident in going about it unless you had something to work with initially.

Kenyon: Right. I still don't feel confident about it.

Workman: When we were first trying to get some of the data points on that matrix for nitrogen diving or air diving, one of the ethical considerations is that you have to be relatively assured that you can completely remove any problems that may arise and any decompression sickness, treating under pressure. And when a bend occurs under pressure, you get these data points. And there was no assurance of that whatsoever. There was very little experience with treating hits under pressure. These are always regarded as a serious type of thing even with a pain in a joint, because you had to then get back to the surface after resolving the situation. So those data were a very hard buy. And I question that we have enough information to extend the data points on down even in the shallow-depth areas. I can remember the frustration of trying to get any of that data. And you certainly have to have as good information as you can to extend these even to low depths, because the ethical consideration still exists. You have to be able to assure yourself and the subjects that you can in fact handle anything that arises, and I don't know who can do that even today. We have a little more experience now but it's taken some time, and it worries you every time you go under one of these data points.

Harvey: Problems of inadequate data also exist when you start changing inert gases in the process.

Hempleman: When doing analysis of caisson data, it was noted that the osteonecrosis which they got was related to the number of exposures.

And that probably was the number of decompressions. And this is the sort of question you would address to a data bank. But what interests me is whether anybody thinks when they do these excursion dives that they are in fact pumping up considerably the number of decompressions that the diver is subject to.

Harvey: The model that Kent Smith has used to produce bone lesions in pigs is based on a frequent repetitive dive schedule, and is the only successful animal model that I know of.

Barnard: Do we actually know of any successful matrix for repetitive dives?

Kenyon: I hope ours is.

Workman: Do you mean coming back to the surface or from excursions?

Kenyon: I think the overall experience with the repetitive diving that the Navy has used has been that the schedules are reasonably adequate. I think they're not being tested as much in recent years and I think there's a tendency to try to do as many of these dives as possible no-decompression. Normally in early testing we will make 8 to 10 dives a day with the same subject for days running, three days as I remember. Obviously, this wasn't the complete test that was scheduled. It was a test scheduled in certain areas of the matrix, and of the hypothesis itself. And I would question too that it's possible that one could do this at all depths and all configurations, but commercial people use a tremendous amount of repetitive diving and multi-level dives operationally, as well as employing the repetitive equivalent procedure for these for which there is no alternate procedure. And doing dives in this way, and many of them very impressive dives to me as I looked at the logs, we have experienced I think between 7 and 8 thousand dives and have had 7 tenths of a percent bends. So, I think the predictions are really not that bad, and far better diving is possible in the population group than in the variables that exist.

Barnard: I think that you've got to be careful here. I think there are at least two sets of data here: those which were laboratory-monitored, excellent dives to test out something where they were properly observed, and those which were recorded as repetitive dives in old logs. Because if you actually talk to divers, certainly in our experience, we found that they tended not to use the repetitive dive system. In fact, some of the divers say they can't understand the USN repetitive dive system. In our experience, when they got to where the repetitive dive looked as if it were likely, they gave up diving. So they didn't really do repetitive diving.

Workman: Of course, when you have a job to do at sea there's very little alternative. I know we've had many divers who dive from morning to night far in excess of anything that I think should have been done, but it was done because the job was there to do. And I rather think the dive record, since they get paid for these things, very probably represents data within the accuracy of your ability to measure depths and time exposure.

Kuehn: In Canada, the Kidd-Stubbs decompression model has been applied both experimentally and operationally on repetitive dives and also dives from habitats and depth, and we find great success with it as well. We think it's as good as the USN for preparing our tables with this kind of environment.

Bornmann: I would like to comment on Dr. Hempleman's statement about bone necrosis in caisson workers. Suppose you have a job that requires tunnelling to 100 feet. If you use a saturation base of 50 feet and do excursions to 100 feet each day, the exposure that you are making the man undergo is a lot less than if he had to decompress from 100 feet back to the surface each day. So in that sense he's really under less strain - and if this connection is true - runs a lesser risk of developing bone necrosis.

Hempleman: Yes, I think it's true, if you're thinking of obeying the system. I think that a margin of the saturation dives was really that you stayed for very long periods, and there took advantage of the excursions from the saturation depth to conduct your affairs from some less deep base and go upwards; now we'll go deeper. If you go to a certain depth and stay there and you dive around and expose yourself continuously around that pressure level, you are not exposing yourself now to variabilities of the gas phase. We have the bends due to compression and then we only do one decompression treatment. If it was your intention, prudence might dictate, but you would go to 100 feet and stay there rather than go to 50 feet and keep bobbing up and down.

Bornmann: I was going to ignore the fact that you said you thought it was decompression rather than the other two phases of the dive. But practicality and economics have to be taken into consideration too. If the health of the workman is not affected, then I think economy will dictate the circumstances of the decompression.

Hamilton: When you're working at 1,000 feet on board a vessel in the nasty North Sea where you can expect a rig abandonment once every eight months or so on the average, you don't want to confine your men to 10 days if you can get them out in 3 1/2. Certainly this is a very strong justification and when you get into the 1,500-foot range the quick bounce from seven or eight hundred feet which eliminates the arthralgia is probably safer and more comfortable for the diver than to saturate him at that greater depth. But this is the approach that we're using, and we've done it in two levels, one working from 500 and 600 feet toward 1,000 feet, and the other working from around 100 feet both upward and downward, in the nitrogen region in the latter case.

I'd like to tie together what Dave didn't say about data banking as it applies to this NOAA OPS project. We took a number of dives and put them on a computer. All the computer did here was simply catalog the information. There was no computation done. A card sorter would have done the same thing. Then we manually arrayed this data according to times and depths and the various sorts of dives, with and without bends in a variety of ways with the computer. But we ended up manually selecting the places where we felt violations were probably occurring. We did operate on the data to the extent of computing gas loadings, because this is the basis of the model that we're using. This is the "transfer function" between an experiment or a dive, and the next one, this decompression model, the matrix and the recomputed profile. It was not very complicated, and once we had a new matrix which was worked up by visual inspection of these dives and once they were arrayed properly, and the profiles or gas loadings were computed, we then plugged it back into the computer and used the computer for computation again to come up with a set of profiles. We can predict for Jim Miller a complete profile if he can give us a two-week program. He says, "All right, we'll dive on Tuesday, we'll do such and such a dive on Wednesday." We have a complete schedule and we can compute the repetitive situation on the basis of assuming that these gas loadings and this matrix really are what applies physiologically, and we can tell him day by day where he stands. You may have noted on one of those graphs, that two apparently identical dives had two different times. The reason for that was that the repetitive schedule would call for a shorter time the second time we did it. And the same thing with this. If we do a morning dive to 300 feet and then we do an afternoon dive to 300 feet, the second dive may be shorter than the morning dive. If we do a long soak at a higher pressure than the habitat one day, then an ascending excursion the following day becomes perhaps unfeasible and certainly much shorter than would normally be done.

As Dr. Barnard was saying, the old system was simply that if you got in the situation where the previous dive affected today's dive, you just didn't do it. You waited until you were in the clear, and then you did it. That briefly brings us up-to-date on what we think is an effective method of using a computer. Ultimately we should be able to apply more experience and let a computer select these things and draw these matrix lines and then we'll take whatever we can get, and if we don't like the jiggles in it we'll go out and get more data. We don't adjust them, we do it statistically.

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SESSION III: POTENTIAL PATHWAYS OF DATA BANK UTILIZATION

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A. KEYNOTED: SURGEON COMMANDER E. E. P. BARNARD, RN

This morning, I will attempt to define what it is we want out of this system, and to amplify some of the points made by yesterday's speakers. The title, "Keynoted", refers to the short piece played before the real concert begins; after this, I shall revert to my role as conductor.

The history of diving is a very good example of how solutions lead to new problems. The High Pressure Nervous Syndrome is a recent example. Trying to process this sort of information for a data bank is exceedingly difficult, because it is hard to define what is meant by a fact. It was emphasized yesterday that data capture - getting valid data into the data bank - is probably the trickiest area in the whole system. My definition of a fact may differ from other definitions. In decompression theory, for example, I would not define the elaboration of a theory, which leads to a calculation, which is used as the basis for a decompression schedule, which is then tested, and which works, as a fact. I recognize that this process may add to our body of knowledge, but it is not an experiment. It is not an experiment because the result may have been influenced by the calculations which were done in the first place. I define facts as empirical; that is, when one tries to find out what can be done in certain circumstances with a minimum number of preconceptions. For example, if a schedule is produced in which the decompression looks like an S-shaped curve, the model must be made to fit that curve, whereas if one begins with the assumption that the curve must be exponential or linear, important possibilities may be excluded. My first point is that it is most important that all the facts we collect be empirical facts.

Once the data are collected, the agonizing process of writing the report begins; selection of some data as significant usually involves discarding a large portion of the data. One of the advantages of a data bank is that the data can be stored, to be reanalyzed and reshuffled in ways which may not even have been thought of when the experiments were first done. The Canadians have shown what sorts of things may be rediscovered in their own data.

In this field, the production of decompression sickness is what gives us nice hard empirical facts; if there are no bends with a particular table, no facts about decompression sickness have been learned. Even with this kind of fact, there are subjective factors which influence it; psychological decisions often enter into a report of a bend. A diver may distort the truth by covering up or ignoring the pain. Even if one treats the diver as an experimental subject, observing him through the port to note any excessive movements in a limb, there are still chances for error: the diver must confirm your suspicion, which he may be unwilling to do, and the observer must notice the signs. We have all met doctors who insist that it is not a bend, but a gardening injury. This information is your only input for schedule testing; whether or not a bend was present gives you the shape of the curve. When one realizes how subjective and imprecise the input is, the business of producing neat mathematical theories becomes extremely suspect. Another complication is that the rate of data accumulation is very slow; if one is schedule testing with saturation dives as Jim Vorosmarti is, one is lucky to do 30 dives in two years. The opportunity to get large amounts of data banked by other laboratories is therefore very attractive, but this practice can lead to the tendency to say that the majority is right and to ignore the odd or exceptional dive. What can't be explained satisfactorily tends to be put aside. I want to give you three examples of this sort of thing, and tell you why I think they're important.

First, some experiments which Jack Eaton did, involving brief exposures of the type used in submarine escapes, from a steady-state condition. (I prefer the term "steady state" to saturation of one atmosphere.) These dives consisted of a sudden dash down to pressure and back again, involving depths to 700-800 fsw. Decompression sickness from this depth is fairly catastrophic; the animals tend to become paralyzed. To evaluate problems which might arise in submarines, he wanted to see what would happen if the pressure in the boat rose before an escape was made. He did a steady-state exposure at some raised pressure, and then superimposed the same dive from that depth; in other words, he did a submarine escape from this new steady-state exposure, which was no longer one atmosphere, but about 50 fsw. He found that the nature of the decompression sickness changed in this new situation; he was getting limb bends rather than the catastrophic forms of decompression sickness. This is a curious finding, because in each case, the first state can be characterized as a steady state, of long duration. The dive superimposed on that is similar, and yet the end points are entirely different. The sort of experiment which we find difficult to explain is a test of any model, and we should use these exceptions to test whatever we have in mind.

The second example is from the field of decompression sickness treatment. We know that pain can become worse as recompression proceeds, and that pain can get worse at constant pressure if the diver is breathing oxygen, and that a combination of these two factors may produce the same result. In 1963, we had made a decision that a diver did not have a bend, even though he was in pain. I got permission to treat him with oxygen, and took him back to 30 fsw on pure oxygen. The other man who had been on the dive volunteered to go along as attendant, largely because he was going into shock, as we subsequently learned from his report. After five minutes at 30 fsw on oxygen, both divers were clear of all symptoms; we kept them at that depth for one hour, and then took an hour to get back to the surface. They had had two hours on oxygen, and another hour between the end of the dive and the recompression, so that by the time we were on the surface again, they had been out of heliox for three hours. However, before I could deliver the diver back to his base on the surface, the pain was back again just as strong as before. In some way that cannot be explained, two hours of oxygen breathing had been reversed by twenty minutes of air breathing. This is another exception that would have to be taken into account in any model of decompression sickness.

My final example concerns repetitive dives. We used the standard air tables from the Diving Manual; the instructions say that to do a second dive, the interval of time must be lengthened. We decided to use exactly the same decompression; we repeated the dive precisely. For example, we did 140 fsw for 20 minutes, and then an interval later we did another 140-foot dive for 20 minutes, using the same decompression. We used a constant interval of 200 minutes between the end of dive 1 and the beginning of dive 2. When this proved satisfactory, we cut the interval down to 100 minutes. These dives were done in water in the Deep Trials Unit in 1965, and a number of similar dives were done in the Mediterranean, and appear to have been quite satisfactory. Later we did a series of repetitive dives; that is, we extended this same schedule to three dives. We discovered a number of things: the table didn't cover the situation and the system doesn't seem to be linear. A single dive to 180 fsw on this schedule cannot be made without bends. Twenty minutes at 180 fsw doesn't work; 20 minutes at 160 fsw was a bit shaky; 20 minutes at 140 fsw was quite satisfactory. Up to 140 fsw, the time for the second dive doesn't have to be lengthened if the interval is as short as 100 minutes. I don't think these results could have been predicted by the model which was used as a basis for these tables. These are all examples of exceptions we should be using to test our models.

Discussion among the participants (Barnard, Hempleman, Kenyon, Miller, Workman, Bornmann, Harvey, Young, and Shilling) elicited the following points: In the Eaton experiments mentioned earlier, where the partial pressure was increased through 50 fsw, did the diver come back to the surface, or to 50 fsw? In response, it was explained that the average bend point was 65 fsw; the dive just dropped a few feet from that and had a submarine escape on the end of it. Instead of getting type II decompression sickness, type I was observed. There are almost opposite observations: if you give an animal type I decompression for six hours and then bring it to the surface, it would be surprising if it had a bend at 50 feet. But if you give it a good stiff dive, 10 or 15 feet below its normal performance level, it will faint and go into paralysis when brought to the surface, as though it had gone from mild bends to the CNS - a severe extension of the same sort of phenomenon.

Titration of diving may help to explain some of the exceptions. This technique is now being used at Union Carbide with neon, helium, and oxygen, in an attempt to find rational data about bends. One of the problems in diving research is the increasing pressure from the outside about the ethics of these kinds of experiments. This particular moment may be favorable for research which will not be possible in the future; if no more than a 2% incidence, for example, was allowed in these experiments, it would take a much longer time to find out what we have to know. The policy of the Royal Navy towards experiments designed to test limits is that if there is no other way to get the necessary information, the experiment can be conducted, but this might change in the future. These are several goals in developing decompression systems; one is that we may be able to make predictions, and the other is that we may be able to provide a completely safe decompression table.

There are good reasons for using conservative estimates of decompression time, particularly if they avoid trouble and delay. Decompression time is cheap, especially when compared to the suffering, time, and money spent when someone is injured. We can no longer afford to think that the Medical Officer will be able to take care of any of the injuries which occur in the course of these dives, particularly in the case of vestibular system injury. We cannot assume now that the individual has a 100% chance of returning to normal. It is also not beyond the realm of possibility that many decompression procedures result in silent bubbles, which produce injuries which take a long time to be manifest. We are concerned that the divers often have to dive again in little more than 12 or 15 hours; is it enough to see that these divers have no overt symptoms of decompression sickness?

To the extent that we believe that the etiology of osteonecrosis is a decompression incident, we must be concerned about asymptomatic decompression sickness. Upon examination, the bones and spinal cords of animals with aseptic bone necrosis demonstrated fairly extensive damage, though they appeared clinically normal on grosser examination. There is evidence for this view of the etiology of osteonecrosis, and it must be taken into consideration. There is a new rule in the U.S. Navy now, that all divers must be autopsied, and this should allow us to examine the nervous tissue which was examined in animals; we hope that the experimental conditions inflicted on the animals do not in any way resemble those used with human divers, and that there will not be any indication of similar damage.

The difference between bends and bone necrosis is that there is an objective end point with bone necrosis; the subjective factors are ruled out. Will the autopsies on divers include radiographs of bones? We could learn a lot if they did. We have a curious situation here: in the case of bends, we are trying to look for a model; bends are a symptom looking for a site. With necrosis we have a site, but are looking for an etiology. We recently analyzed some data which some statisticians had also interpreted. The statisticians were trying to say that bends protected against bone necrosis, when what the figures actually said was that both were correlated with pressures, so that a diver may get bends or necrosis or both or neither, in about the right proportions.

The question of how computer banks could be used to define the relationship between human and animal experience more clearly has been raised. It might help if we could use animals larger than man, which are more susceptible to decompression sickness, as our test subjects, instead of using smaller animals, which are less susceptible, and then adding a safety factor when we extrapolate to humans.

A final confusion that needs to be cleared up is the use of the terms computer and data bank synonymously. We should remember that we have not yet decided on a system. Also, the workshop on the ethics of hyperbaric research that was held last June in Stockholm agreed that everyone engaged in hyperbaric research was negligent if he did not have full knowledge of all the previous animal and human experiments that had been done. We do need a central data bank for this reason, and perhaps also for our own legal protection. The meeting ended with a plea for hard data, before procedures which can have such enormous ramifications are instituted.

B. DATA BANK UTILIZATION: MR. PETER EDEL

Divers are very sensitive about how their decompression or experimental schedules are calculated. It helps to inspire confidence if decompression calculations are computed on the slide rule, for it automatically seems to confer some special advantage to the tables, as opposed to those worked out on paper, with just a pencil. This is even more true with computers, for they seem to generate a mental picture of a miraculous machine which is both infallible and unlimited in performance. The decompression schedule which is privileged to bear the title of computer-generated inspires much more confidence than one which was calculated even on the basis of vast experience. This, in a sense, is unfortunate, for the computer is often put to use in areas which are beyond its present capabilities, and often in areas where many of the problems are as yet unknown.

We must remember that the computer is merely an extension of our own minds: if we have not fully understood the problem that we place before it, it can not help but fail us. At present we can calculate decompression schedules. Our schedules may not produce the desired result on initial trial, but at least we can modify them in a reasonable period of time and be guided by the results of the test chamber.

We should ask ourselves just how we expect the computer to help us or in what manner it can help us. Obviously we would like to have a computer about the size of a wrist watch which would sense all the pertinent factors, indicate decompression schedules no matter what we breathed, how deep or varied the depths were, or how long we stayed, regardless of the conditions. Oddly enough this idea didn't seem ridiculous to some designers, and some prototype units were built. While not of wrist-watch size, the units were small enough to be included in divers' equipment. Needless to say, a few tests in one form or another usually change the optimistic attitude of the manufacturer. If we rule this device out at the present time perhaps we can consider some other alternatives.

Computer programs can be designed to provide safety compression tables for data which is entered into memory banks without any human intervention: data in, schedules out. The second type is the same as the first, except that humans are put in the system to provide compensation and evaluation. We program the computer with individual formulas to provide printouts of the decompression schedule: formula in and schedules out, but with human intervention. The provision for human intervention may appear to be a minor change, but is really fundamental. In one case it is assumed that the computer is totally self sufficient, or more correctly that the program is totally free from error. If our assumptions regarding the operation of the computer are in error, the computer obviously must be in error, so we cannot free ourselves from human frailty.

There is a tendency to supply maximum amounts of data to the computer so that incorrect data would not have a statistical significance, but this assumes that the poor data is in the minority. Another assumption is that all data can be equated together, i.e., that decompression profiles are decompression profiles regardless of the type and conditions of exposure.

Considering the two assumptions, let us suppose we have seven sources: A, B, C, D_1, D_2, D_3, and D_4. They all use different formulas and have different success rates. A and B are across the board and A claims to calculate decompression schedules under any and all conditions with 100 percent success. C has 100 percent success with limited conditions and D_1 through D_4 have fairly high percentages of success under limited conditions. Limited conditions might apply to bounce dives, saturation dives, caisson workers, decompression on air only, decompression from helium-oxygen, etc. It might appear that A has the problem solved for us, but when investigated the data fail to live up to promises. C may have 100 percent success but the application may be too narrow to be of help. Can D_1 schedules of decompression on air which prevent bubble formation in the early stages be used for D_2, whose schedules allow bubble formation to occur in early stages requiring a reduction in values in the later stages? Can any of these values be applied to total saturation applications with nitrogen and oxygen which appear to require extremely low m-values for some as yet unexplained reason?

Certainly the most limiting conditions from each decompression category could be utilized with nitrogen-oxygen for air diving as a whole, but with the resulting loss of specific decompression advantages. This is equivalent to taking the present m-values for helium, hydrogen, neon and nitrogen and attempting to draw a final set of m-values for all conditions, where such an attempt could be extremely restricted in terms of what we are able to do in each of the independent areas.

Again we have problems when we start to put data into the data bank from different conditions. In the Air Force studies, the average subject population age group may be half of that used in a program involving diving studies. Military research may use subjects in much better physical condition than can be found in commercial diving groups. However, on the other hand, they may use some divers who are very old by commercial standards. The commercial divers may be exposed more frequently than perhaps the average, and they may be better acclimatized than other diving groups. Caisson workers may be exposed five days a week, which may be far above the average of the other group.

When we get down to the individual and look at a specific set of data, generated from many programs, it is important to ask how many questionable areas exist in the program. It can make a world of difference whether the subjects used were of average susceptibility, highly resistant, or highly susceptible to decompression sickness.

Another problem is motivation of the subjects. Some organizations apply penalties to the subject who is found to be susceptible to decompression sickness and at one time caisson workers were fired on that basis. The workers soon stopped reporting their symptoms. As a result, the decompression data coming from that group was highly suspect.

Commercial divers offshore know that there is no increase in pay for the time they spend in the chamber for treatment of bends, and therefore the incidence frequency is questionable with respect to decompression profiles.

If the diver reports a hit and is treated, he may be restricted from diving duty, and the money involved is considerable. Therefore, some cases go unreported. In cases of subjects who are paid on an hourly basis, there may be an incentive to interpret questionable symptoms of bends and magnify the subjective sensations which are reported. Investigators working in these areas are often aware of the problems and make the appropriate allowances for them. This information is rarely ever applied to the computer which, as a result, may produce biased results.

If the actual diving logs are used as data, other special problems are encountered. For example, maximum depth is usually entered on the diving log. If the depth is recorded as 300 feet, the diver may have been working at that depth for perhaps five to ten minutes and spent 50 or 55 minutes at 240 feet. Commercial divers receive additional pay for deep dives based on the maximum footage.

In addition we have the problem of accuracy, especially in accuracy of depth-keeping offshore. The gauges may have tremendous errors in them and there is often collusion between the keeper of the diving records and the diver. For example, a dive with a maximal depth of 285 might be listed as 300 for that extra pay. As a result I have a very low level of confidence in open-water diving records in general, and I think they should be viewed with many reservations. All this is absorbed into a computer on the same basis without reservation unless we are able to call it otherwise.

When the factors are recorded faithfully on experimental diving logs, more often than not the records contain information the particular investigator in question was interested in at the particular time in question. Hence, most of the data has holes in it for general purposes and must either be thrown out or entered into the memory banks with the missing pieces; this is quite a problem.

Finally, in chamber diving many subtle differences in test methods are used which are not recorded in a form which would provide the required information to the computer. For example, during oxygen breathing in an immersed test in a helmet, the shifts in oxygen may sometimes result in a comparatively low oxygen level as compared to a test involving a demand mask. This distinction is logged on the computer where the shift is simply entered as a shift and the breathing mixture referred to as the supply mixture at the indicated time. Once our memory banks have obtained all this information, our problems really begin. We have to ask ourselves, how do we treat this massive data?

A few additional considerations: Do we program the computer to calculate inert gas transport in accordance with Gill's theory? Do we base the calculations on bubble growth formula, on the single tissue model, on Haldane's model or on what? Most of us probably would use a modified Haldane model, not necessarily because we know it to be correct, but rather because of the vast body of experience that we have had in using this model. Decisions, however, are just starting. How does one assume uptake and elimination of gas to be reciprocal? I think Behnke has shown that the elimination of gas varies according to the exercise level of the subject.

In diving we have a man who is producing a considerable work load while he is at depth and an inert gas is being taken up by his body tissues. At decompression this man is at rest, and presumably the inert gas is being eliminated at a slower rate compared to his gas uptake prior to decompression. In programming the computer, do we act on the assumption that uptake and elimination times are reciprocal, or do we assume that they are not? Do we follow Buehlmann's assumption that, for example, a 480-minute tissue is a 640-minute tissue if we go into a sleeping period? If we assume that they are different, then do we assume a fixed difference? And if so, what is the value of the difference if the ratio is not fixed? How does it vary with time? What is the new numerical value for this difference? When we talk about the slowest tissue, again what do we really mean? If we, let's say, use a 500-minute tissue as the slowest one, are we referring to the average for the diving population, and if so, don't we have reason to expect that there are some people with much slower tissues and others with much faster? This becomes a very elusive thing.

In dealing with oxygen, how does elimination vary with depth, or more accurately, the partial pressure of oxygen during decompression? This brings up the question of the effect of oxygen partial pressure on gas uptake during the period of time the diver is exposed to maximum pressure. Do the m-values represent inert gas, or is oxygen to be considered in the sum of the tissue tensions during decompression? If so, to what extent? In all cases what are the numerical values used in connection with the assumption considered? These are all questions which have to be decided one way or another in using the computer to calculate these schedules.

The m-values appearing on the computer printout will be affected by the alternative selected in making the assumptions used in the computer program. A dozen different computers will produce a dozen different sets of m-values of the same data. This, in itself, might not be so detrimental if the m-values were believable. The resulting m-values would not help reduce this inconsistency as we vary the environment. The result is the same problem that we face in everyday practice.

Decompression computations produce decompression sickness. In view of these other considerations, I don't really see how the additional initial two methods, A and C, could be used to produce valid decompression tables until the information is available to solve these problems. In the meantime the data bank only serves to file material for the benefit of the individual investigators who can draw upon the material as required to aid them in solving specific decompression problems. This goes back to the data bank becoming an elaborate filing system which might be somewhat questionable in terms of justification until you start to need it. For example in the NIOSH Committee, it was a requirement to look into hypobaric/hyperbaric decompression schedules. I had no way of knowing where to look for them, but the data bank came up with some human schedules. If it hadn't existed, I wouldn't have had those for a basis to work with. This is just one out of a great many instances where this could be extremely valuable.

This brings us to another problem. If the computer is unable to accomplish such a task in terms of calculating decompression schedules, how can the individual investigator develop the decompression schedules used for this particular requirement? He has got to ask himself the same questions. To begin with, such individuals often do much of their work in areas with which they are extremely familiar through past experience. In working in different areas of decompression problems, the methods used to arrive at a solution vary subtly, and the resulting changes may show us a significant deviation from the basic approach and solution. Each investigator will use a different method of calculation than his colleagues in general. I don't think any two calculate quite the same way. In some cases the difference may be relatively small, in some cases the method may be vastly different. However, the basic method is continually modified to fit empirical data.

The assumptions may be modified according to the particular nature of the call. Whatever the initial basic assumptions, other assumptions can be made to correct the inconsistencies to the basic formula in a particular area concerned, based on past experience in that area. As a minor consideration, consider the calculation of a pressure profile involving a bottom mixture of 50% nitrogen and 50% oxygen at 100 feet. With decompression on oxygen at 30 feet, gas uptake on the bottom will normally be calculated on the basis of 50% nitrogen, and elimination at 30 feet will often be calculated on the basis of 20% nitrogen. This is when pure oxygen is used. Now obviously these two do not match. Undoubtedly the method will work for the individual because the assumption fits previously determined decompression requirements under similar conditions.

Obviously such an inconsistency does not represent a true condition, and could cause confusion when compared with data under other conditions, for example, when normoxic nitrogen/oxygen mixtures are used throughout the entire pressure profile. Obviously the investigator, whatever his method, will make his formula work for him.

Since many decisions and evaluations may result in inconsistencies, the "hands off" approach does not seem to be feasible, at least as an initial step. The advisable approach appears to be using the computer as an aid in producing decompression schedules. Aided by experience and empirical determinations of such schedules, the decision-making process can perhaps be gradually incorporated into the computer approach.

A discussion period followed in which Barnard, Edel, Feld, Hamilton, Harvey, Hempleman, and Kenyon made the following comments.

One of the simple ways to clean up the data is to use a recorder for the depth/time course. Another suggestion is to go back to some of the early work and repeat it, using more modern equipment and methods.

Models have been built which use pigs breathing different types of gas: nitrogen, helium, neon, and mixtures. With no symptoms and no bends, titration of the pigs' data was not sporadic as might have been expected; on the contrary, the nitrogen had one value, neon another value, and the mixtures still another value. Each situation is independent regardless of the model.

With repetitive exposure Dr. Reeves was able to titrate dogs so that she could predict within a few feet where there was going to be a hit, but it was highly individualistic to the animal as opposed to the group. It is important that data of this type be recorded.

There was general agreement that there should be human intervention in designing schedules, and that the computer should be used as a tool for doing this. Another point was that if there are many parameters in a model it is necessary to have many dives to validate the model.

C. COMMENTS: H. V. HEMPLEMAN, PH.D.

I wish to return to the diving-data-bank problem from the user's point of view. There are three principal categories of diving data bank users; namely, commercial groups, military organizations, and academic institutions. The questions put to the bank would almost certainly differ in character from one user to another. For example, one of the principal objectives of the work at my laboratory would be summarized as formulating procedures whereby men may be exposed to a variety of hyperbaric conditions without suffering any short- or long-term effects. This would hardly be considered a suitable objective for academic institutions to embrace. They are much more concerned with the enlargement of human understanding, and therefore, become involved with pursuing underlying mechanisms rather than their consequences in a certain restricted set of conditions relating to human exposure.

Commercial groups who use a data bank would obviously benefit from deducing from the bank's information items some form of procedure which has an advantage over their competitors. For example, if a commercial diving group were to uncover a set of rapid-decompression procedures that did not lead to decompression-sickness problems, then this would be a distinct commercial advantage to them. It follows from such observations that large commercial groups who are operating with their own research laboratory support would be unlikely to donate valuable data to competitors who are not carrying such expensive overheads. It is difficult to see any easy answer to this particular problem.

It is now necessary to examine whether the computer program can cope with the extremely wide variety of information which it will be necessary to store. First, let us examine the two basic diving variables, pressure and time. Diving pressure-time courses vary from those of a few seconds duration to those with many days involved. These two extreme situations may be illustrated by considering the separate problems posed by buoyant ascent procedures from submarines or submersibles, and at the other extreme the pressures and times involved with prolonged deep dives using oxy-helium breathing gas. Recording the pressure every five seconds is quite necessary for the brief-exposure diving, but would represent a monumental amount of information when transferred to dives of several days, or even weeks, duration. On any single-dive profile, there are five important pressure-time phases for information collection. First, there is the predive phase where important control information may be collected over several days or weeks on the subjects. Second, there is the comparatively short compression phase which may involve certain important changes in behaviour of the subjects, e.g., tremors. Then there is the third phase varying in duration from minutes to days, when the divers are at full pressure, which is followed by the very important fourth decompression phase, and finally there is a fifth phase which may go on for months or even years, to determine whether the dive could be said to have resulted in any chronic ill effects. So far, only single exposures to pressure have been considered as though they were isolated items, but of course, everyone here realizes that repetitive diving is extremely important. The number of independent possibilities here is dismaying, depending, of course, on the number of repetitive dives. Suppose, however, we only consider double-dives. Then one is constrained to record the pressure and time of the first diver, followed by the time interval before the commencement of the second dive. With such a wide variety of combinations possible, and with the added complication that divers may use a number of breathing gases at different stages, the whole situation becomes appallingly complex.

Next worthy of mention is the statistical problem. In the United Kingdom a number of large compressed-air contracts were completed by 1964, and it was possible to state that from 240,000 exposures to compressed air at pressures in excess of 14 pounds per square inch gauge, there had occurred twelve cases of bone necrosis of sufficient severity to warrant surgical intervention. Thus, the incidence rate is one in twenty thousand for the severe form of osteonecrosis, using the particular regulations for working in compressed air that pertained prior to 1964. With such a low incidence rate it is obvious that a vast number of observations will be necessary to establish the effectiveness of any new decompression procedures that may be suggested. A diving-data bank must, therefore, be constructed in order to accept literally millions of dives with possibly several different decompression procedures involved, and it is essential that those persons subjected to a particular decompression profile should not be mixed and confused with those who have been regularly exposed to another form of decompression profile. This latter requirement not only means a massive amount of extra work, but it also means that the work must be carried forward with great precision, because identifying two or three cases of osteonecrosis incorrectly with certain decompression profiles would wreck years of data collection, due to the low incidence noted above. The same problem arises in diving activities, such as buoyant ascent procedures. Many hundreds of thousands of exposures are performed in the training tanks throughout the world, and there is an incidence of about one in ten thousand of severe decompression sickness as a result of these activities. Here again, the effectiveness of any suggested modification of escape procedures would require vast record-keeping facilities.

Finally, I would like to discuss a matter which has already received considerable airing; namely, the reliability of data which is placed into the data bank. However, I would like to approach the problem from a different standpoint. This would be best illustrated by an example. An attempt was made by Professor Walder to compare the effectiveness of two different decompression procedures being used by tunnel workers. One set of procedures had been used for decompression of U.S. caisson and tunnel workers, and the other set of procedures had been used for the decompression of U.K. workers. To measure the effectiveness of the two procedures, Professor Walder used the numbers of cases of decompression sickness sufficiently severe to warrant recompression per hundred entries into the tunnel. Immediately there arose the subjective problem of deciding whether two different groups are using the same indices for assessing the severity of decompression sickness. It was common practice, both in Europe and the United States, for tunnel and caisson workers to hide their aches and pains due to fear of dismissal from employment, or to ignore any minor troubles as not worthy of mention. Throughout the western world, considerable re-education of air workers has taken place and it is reasonably certain that the air workers are now reporting to the medical centers incidents that would have previously gone unmentioned. Despite this increased awareness, there is nevertheless a doubly subjective decision occurring, namely, the air workers' recognition of any symptoms, and the doctors' judgment as to whether this is worthy of recompression. Considerable mistrust can build up between various groups when one group is apparently not reporting as many cases of decompression sickness from similar working conditions as another group. This mistrust is very regrettable, but of course quite understandable in light of not knowing the standards employed by groups other than your own. It seems that there may be two ways out of this dilemma.

In the first place, some form of objective end point could be devised for assessing the outcome of a decompression profile, but the likelihood of this happening in the present state of human knowledge is very remote, and for marginal symptoms ensuring that all divers are adequately screened after every dive would be a formidable administrative task.

The second, and to me more feasible possibility, is that there should be some form of interchange of personnel. Only in this way can confidence in the diving data be established on a national or international basis. We have been very fortunate at RNPL in seeing many different groups of diving research workers trying out procedures in our pressure chambers. It is extremely helpful to see for oneself the manner in which other workers approach a problem and the weight that they put on evidence that they themselves have collected. In addition, we have had officers of the calibre of Captain R. C. Bornmann and Commander J. Vorosmarti working at the laboratory for periods of approximately three years in each case. Thus, in a small way we can speak with some authority about the benefits to be derived from cooperative ventures and exchange of experienced personnel.

I took as my example of the need for cooperation, the assessment of bends, which is, of course, principally a clinical matter but I could quite well have chosen such other topics as measurements of diver performance, biochemical techniques, hematological procedures, with particular reference to the recent sets of disparate results on post-dive platelet counts. Every area of diving research, covering disciplines ranging from engineering through physiology and on to pathology, benefits markedly from interchange of personnel, and this in turn leads to greater confidence being placed on the data stored in computers.

Harvey: I think if the investigators, when they are planning protocols which will need data, were to properly utilize these data banks, the data bank would have time to actually act as an interface to tell them the experience pertinent to the experiment that they are going to do. This is an aspect of data banking that's been rather neglected.

Kenyon: This is true. We have abandoned our attempts at data banking because we can't do it efficiently, nor can we do it for the amount of money it takes to do it, and we are giving all our support to the University of Pennsylvania.

I think a great deal of emphasis should be put on key fields. In other words, what was done and what are the results. Whether we ever get the whole profile into the bank or not may be relatively secondary. If the profile exists on a printed page, or in a file drawer or in somebody's mind and can be retrieved from there, knowing it exists, being able to extract the fact that this series was done, is to me the single most valuable function of the data bank.

Hamilton: We have a couple of filing systems in our laboratory that are relevant here: one in which we put all the catalogs that come in, innumerable stacks every day in the mail, and the other is just the reprints and technical blurbs. The philosophy that we use is to make a system so that they are as easy as possible to file, at the expense perhaps of having a little trouble in finding them when you want them. You must arrange it so that the particular dive description gets into the file. At the very least, maybe a simple profile, perhaps two or three words describing the depth, the time, the gas, and who did it, something like that. So that you can make a search and the data bank will go into business.

Kuehn: We feel data banks are a realistic possibility, and that the computer system is more than adequate to handle the decompression that has taken place to date and possibly for the next few centuries as well. For example, in CANDID we have the raw material that had to be used to form the CANDID bank in several filing cabinets consisting of papers weighing 250 pounds. For anyone who had to go through that and analyze this data to pick up a different reason would have taken many man-months of a professional's time. Now this is data that has been put into the computer system. We have it now in one magnetic tape. Addressing this data now takes about five minutes to ask one specific question concerning research. The capabilities here are enormous. We are just overwhelmed at DCIEM by the fact that we have now a tool that is far more comprehensive than we can in fact use. This information should be available to the world-wide research community. All the decompression data in the world could be put into a decompression system. Transferring all the data can be done in three or four magnetic tapes. There is no question that computer technology is more than adequate to handle a decompression history.

Hempleman: I think we are in a position now where they were with language machines. As you know, I think this is more than they can handle. Let me use as an example the principle of the pressure-time courses. People would smile if you said clock every second. But there are certain classes of dives which are very important to people, such as those in submersibles. We found, for example, when you put pressure-time recorders on following ascent profiles that these people who get out of a submersible or a submarine to ascend through the water do not all ascend with uniform velocity. If they have some sort of clothing on, some of them seem to fiddle about before they reach the streamlined shape necessary to reach a uniform velocity. So if you were measuring them just from the time of leaving bottom and time on the surface, and dividing by the distance that they traveled up to the water, this is in fact not the pressure-time course. If you handle the millions of pieces of data, you will find that it is very difficult to answer questions. Does the time interval between the work periods influence the outcome of the decompressions because there is a continuing stream of stuff going on, and the down decompressions have a change because quite often the tunnel pressure changes? You are handling a constantly varying situation with the labor force changing and people getting ill and when you actually come down to extracting out of hundreds of observations something that is statistically valid, it is very difficult.

Workman: I would certainly agree with many of the points that Peter and Val made. We have the same problems of evaluating the experience in operational diving. We also are handling data on our processing of divers' bone surveys, and this isn't a terribly large number, but to attempt to keep current on the data and our experience is difficult. Our decompression experience, of course, as we take a look at it, consists of logs from the operational divers that we have on several different places around the world, which makes for some problems.

D. COMMENTS: ROBERT D. WORKMAN, M.D.

My discussion will relate to the special case of data handling in commercial diving. We attempt to evaluate our decompression experience from the diving logs maintained by divers at many different sites throughout the world, and to evaluate about 150 divers' bone surveys per year. There are problems with the adequacy of data recorded in the diving logs and even in getting all the logs returned to our office to ensure that all the data are available for publication.

In the past year we have had 668 helium-oxygen surface-to-surface dives, mostly in the depth range of 200 feet. There have been a few dives that have used the 300 and 350 feet schedules, but for the most part, dives at that depth require saturation diving to accomplish the work of construction diving which is not possible by surface-to-surface diving. We have about 150 men decompressed from these saturation dives per year, so we are interested in the adequacy of these decompression procedures as well as those for surface-to-surface dives. The surface-to-surface dives have produced about 0.5% bends, while all the saturation dives have produced about 1.7% bends.

Our Company does 7000 or more air dives per year, which accumulates a large pile of diving logs and requires a great deal of time to evaluate. The air dives have produced about 0.7% bends incidence. We produced a higher incidence of bends, and as a result have been able to modify these to make them more adequate, particularly on the helium-oxygen dive schedules. There are always problems like the increased number of bends experienced by the same divers, perhaps due to greater susceptibility, which complicates the evaluation of adequacy of these schedules. Accurate depth keeping at the decompression stops in rough water and evaluation of the accuracy of the pneumofathometer depth gauges are additional complicating factors of concern.

The effect of cold-water exposure on divers' circulation is a variable factor between dives, as this affects the adequacy of decompression. With saturation diving, we use hot-water suits to keep divers warm, but this is seldom possible for surface-to-surface dives. Since these variables are not the same for all dives made while using the same decompression schedule, evaluation of adequacy of these schedules is complicated.

Basically we use the U.S. Navy's helium-oxygen decompression schedules with additional conservatism built in by deeper-water stops, more decompression time in the deck-decompression chamber and with bottom time limited to that which makes a safe surface interval possible. Our schedules are in most instances about double the ascent time of the U.S. Navy schedule. They were based upon the experience of thousands of operational dives over the years in which hard work was done by the divers; these dives demonstrated the need for this amount of additional decompression time to provide safe schedules. Our effort has been to minimize the number of helium-oxygen decompression schedules to 50 feet, increments of depth from 200 to 350 feet, to ensure uniform application of the schedules and to provide a maximum amount of information on the use of these schedules. Should evaluation of our experiences indicate problems with any of these schedules, we are in a far better position to make appropriate modifications and view the results of this action.

It is obvious that we make no attempt to minimize decompression time used for divers; our goal is to prevent a diver from ever having bends, as this affects him and the steady flow of work adversely. Even though some may consider the amount of decompression used on our schedules to be excessive, we prefer to avoid at all costs the uncertainties that arise in diving operations from treatment of bends. We use decompression time to eliminate these risks and the uncertainties of being able to keep the operation going and the men diving uninterrupted by bends and treatment required.

We use surface decompression with oxygen for air dives exclusively and do the same even for dives that should require no decompression. Divers have sustained permanent spinal cord injury from no-decompression dives, so that if a little investment in decompression will prevent this occurring in the future, we feel it is warranted.

Data extraction and reduction from all the logs of these dives is time consuming and boring, but all this would have to be done manually before reduction by computers. It would require a considerable cost in personnel and computer facilities and time to do more. I feel that these costs could be disproportionate to the information we presently derive from our own efforts with a minimal number of people.

We have accumulated over 400 divers' bone surveys since 1971, recording this data manually. We find a very small number of divers affected by aseptic bone necrosis, six in all out of this group, so the processing of their data is not complex. We are running about 150 bone surveys a year, including repeat surveys on our regular divers.

It is difficult to determine meaningful relationships of aseptic bone necrosis to diving experience or bends from the small number of divers who have developed positive bone lesions. Many of our divers have dived for a number of years, experienced bends and been treated for this by recompression several times during their diving careers, yet they show no evidence of aseptic bone necrosis. Several divers with positive bone changes have never experienced bends.

Since many of our divers have done both surface-to-surface and saturation diving, one cannot relate either type of diving experience to bone changes. None of our divers who have done saturation diving have demonstrated lesions of aseptic necrosis at this time.

The most difficult problem with evaluation of the divers' bone surveys has been to ascertain with certainty whether lesions present in bone are those of aseptic necrosis or other sclerotic changes such as bone islands which are seen in at least one-half of all the divers' surveys. Use of coned spots and planigrams, and six-month repeats on these surveys have been helpful in defining these bone lesions.

I have expressed doubt concerning the usefulness of data banking to us as this related to decompression schedule use and for divers' bone surveys. Neither do I feel that banking of data on dives would be very useful due to the many variables inherent in data recording, personnel involved, and procedures conducted. In addition, the complexity of doing this, the number of people required to do it and the overall cost are, I feel, out of proportion to the possible value to be derived in our particular situation of operational diving.

In a similar manner, I have not been much impressed with the usefulness of computer programs in generating decompression schedules. I have had experience in the past where excellent analog and digital programs, and personnel familiar with schedule development were available, and yet a great amount of further effort was required to put the schedules generated into useful format for use and testing. A lot of this could have been done at the time the schedule was calculated manually with the flexibility to make decisions along the way. It is difficult, if not impossible, to anticipate the nature of all the decisions required in dive-schedule generating to be able to insert these into the computer program.

SESSION IV: CONCLUSIONS AND RECOMMENDATIONS

SESSION IV: CONCLUSIONS AND RECOMMENDATIONS:
SURGEON CDR E. E. P. BARNARD

In this final session we shall attempt to draw our conclusions, and since it is easier to disagree with someone else's conclusions than to draw one's own, I will make some suggestions before Jim Vorosmarti spells out what the user wants.

My point of departure concerns the way in which scientific inquiry is described; I equate the body of scientific knowledge with the total information in a data bank. An investigator first takes the abstracts, reprints and other prior knowledge from that data bank, then analyzes it to decide what information is to be believed and what not, so that he can decide which hypotheses deserve to be tested.

Data experts, including the editors of the publication to whom the work is submitted, decide whether the experiment's results will go into the body of scientific knowledge or not. This analogy is fitting because in a sense the proceedings of this meeting are another item of data which will go into the bank on this subject. This meeting is an attempt to set up a control system for these data. Specifically, we should ask the Undersea Medical Society to help in setting up a new meeting on the question of data bank systems in three years' time. In this way we shall have feedback to show whether we have achieved what we set out to achieve, using the same sort of group we have here to make that determination. If there is no future meeting we shall have no control over how the system ultimately evolves.

I believe we need clean data, and most of us also agree that more data belongs in the data bank. The experiments which so many of us have performed but never written up because they were incomplete would fit into this category. The data review which precedes publication needs to be done on the basis of a scale with several categories. We must analyze the relevant data and categorize it according to its usefulness to this system by submitting it to a group able to complete this process for us and put it into the data bank. There are two categories of data: first, information in the restricted sense of data on which decisions are based, to be subdivided into reprints, articles and crude diving data of the scientific type; second, the general body of experience, such as sea-diving data and data in a category lower than that of scientific data.

I believe we should send the published information from the old system to the data bank in Philadelphia so that they do not have to search to see what has been published previously. It is necessary that the scientific committee associated with the International Data Bank form the committee responsible for examining the categories of usefulness. Once formed, this committee will say whether data is scientific, pertains to sea diving, or belongs to a lesser category of usefulness. Information can still be stored and assessed but it will be clear that it is not hard scientific research data. The same scientific committee might compile a catalog of potential users.

General discussion elicited the following points. The committee which agreed to serve as the scientific board includes: Dr. Ackles, Dr. Hempleman, Dr. Lambertsen, Dr. Chouteau, Dr. Buehlmann, Dr. Hester and Dr. Nashimoto. There does tend to be a conflict between different centers and different types of source banks. There should be one bank to store experimental data that comes out of the laboratories. Although the participants agreed that they should support the choice of a single bank, some wanted to know if there was any alternative to the University of Pennsylvania location. The distinction was then made that the bank would merely be called the International Decompression Data Bank that originated at the University of Pennsylvania, and that it would be open to the entire diving community; if the diving community and the scientific advisory board were later to decide that another place could do the job better, then the bank should be relocated.

CANDID's purpose here could be to analyze the possible functions and models in the way an operational research group might. This is all relevant to experimental scientific diving and not to operational diving which is already handled so well by the United States Navy. The data bank is already quite sophisticated with respect to the latter type of diving and it would be well to receive access to that material from a large data bank for experimental purposes.

The USN, CANDID and University of Pennsylvania systems are compatible systems, capable of being linked in one way or another. We should certainly recommend that the three collaborate, for if they do so they may develop independently without presenting a problem. There is currently cooperation among the banks, not conflict, and there is no reason why they could not contribute to each other. The data on which an investigator has based his publication should go into the International Decompress Data Bank. One should ask for the raw data as well as the results of his analysis since much of the original data has been ommitted from published articles. There should be a dichotomy between the published literature and the raw data because each is concerned with a different function. The United States Navy bank would probably not be willing to store civilian experience on U.S. Navy tables. In fact, all data banks, including the International Decompression Data Bank, are confronted with a lack of individuals coming forth with questions for them. The data banks are already far more advanced than the questions they receive. It is the user who is the problem.

The next planned step is for an analysis program to interface with the data bank. Before returning to this, let us turn to

Commander Vorosmarti for his ideas on what the user of a data bank desires.

A. INTERNATIONAL INFORMATION EXCHANGE: CDR JAMES VOROSMARTI, MC, USN

As a potential user of a Diving Data Bank, I have been asked to concern my remarks with what I would like to get out of such a system. Before I talk about any specific output, let me first speak generally about two demands I would place on a data bank.

The first is that the data I get from the bank must be accurate. When data are being collected from many points much more control is needed over the collection and review of the input, than when one person is doing an experiment. To illustrate, let me pose some questions which have to do with the present system for U.S. Navy diving statistics. How accurate is the incidence of decompression sickness occurring on air dives to the depths and times required for requalification? I ask because many of these dives are reported for administrative purposes without actually having been made. How many times is the current at the diver's depth actually measured (and particularly to an accuracy of 0.1 knot)? How often are the surface-water temperature and water temperature at depth measured? Who estimates whether the diver is of a lean, medium, heavy, or obese build? Under accuracy of input data also falls the problem of standard definition of terms. An obvious example is that of the problem of individual interpretations of symptoms which may be reported as bends or niggles, or not reported at all. This area also includes the reporting of laboratory data. A single numerical value for a biochemical test is not of much value if the method and the normal ranges of the laboratory are unknown.

My second basic demand concerns the output side of the system. This demand is that the information in storage can be retrieved easily and in variable formats. This means that there must be a great deal of flexibility built into the program. This may strike one as an obvious requirement but it isn't. For example, I recently requested the following information from a data bank: the total number of man dives involving saturation exposure (which was defined as longer than 18 hrs at one pressure), the gas mixes used during the dive, the decompression schedule used, the number of cases of decompression sickness reported, the depth of onset of symptoms and details of treatment. The printout I received contained the following: the dates dives were made, names of divers, activity at which dives took place, purpose of the dive, type of breathing equipment used, type of dress, the gas mixture used on the bottom, the depth, the duration of dive in minutes, schedule followed and whether cases of decompression sickness occurred. Aside from the fact that I received a lot of information I did not want, it appeared on the surface that the data included what I did want. However, on examining the data I discovered several other problems. Most of the dives had no bottom times listed and many of the ones that did were not saturation exposures. The information on the schedule used stated merely yes or no, which is obviously of no help. Knowing the gas mixture used on the bottom can be misleading since that may be the breathing apparatus mixture during a dive and not the mixture used at the saturation depth. Therefore, in addition to a lot of unwanted information, the other data was either not given or in many cases was misleading. On questioning this printout, I was informed that it was the only way the output program worked even though some of the information I wanted was in storage. For my purposes and I assume probably for many others, this data bank was almost useless. This must not be the case in any data bank that I can envision using.

There are two specific areas in which a data bank may contribute to studying some of the problems of divers. The first is the collection of basic statistics of diving as illustrated above. The most important use that a data bank can be put to is in the long-term study of divers' medical history in relation to diving. Ideally this study should include all divers and be inaugurated as soon as they begin diving, i.e., diving school. It would include their complete medical history from that time onward: physicals, special studies, injuries, pertinent illnesses, etc. The diving history would be an integral part of this and include all dives made, whether professionally or for recreation, and any problems associated with any of these. This is the only way I believe that we will gain the knowledge required to understand long-term problems such as aseptic bone necrosis and possible late central nervous system changes. The system should be able to answer a great range of questions from the simple administrative type, such as when a man is due for his next bone survey X-ray study, to a complex one involving any number of variables and correlations.

I would hope that such a program is feasible because anything short of this is probably a great waste of money and effort. In closing I will mention one purpose of a data bank which has been much discussed over the past several years and that is a decompression data bank. I cannot see how the collection of great stores of data on thousands of dives using many different decompression profiles will aid in discovering the secret of universally adequate decompression schedules. The effort involved in this would produce more if it were channelled into a great deal more basic research in inert gas exchange <u>in vivo</u>.

Barnard: I'm proposing to equate what has been called decompression histories with the scientific diving data I was talking about earlier, and I am suggesting that it is the proper stuff to go to the University of Pennsylvania. I am uncertain where you think the literature should go. Perhaps you have suggestions about that. Next, the problem of the Longitudinal Health Survey type of thing, the diving and medical histories.

Shilling: My comment is on the literature storage, analysis and retrieval part of the problem. I am convinced that there is a real need to know what has been done. Some very senior people say: "I know everything that has been done in my field that is worthwhile".

It is easy to show that they are fooling themselves. Some people say they get their information by browsing; others get all their information from reading the 5 or 6 "most important" journals in their field. When I tell you that the 1764 abstracts appearing in Underwater Medicine and Related Sciences: A Guide to the Literature were of scientific articles appearing in 168 different journals, it is easy to see that the browsers, and "important" journal subscribers are also fooling themselves.

Through a suggestion from an ONR scientist, the Biological Sciences Communication Project (BSCP) of George Washington University started a card-alerting service dealing with meningococcal meningitis. Each month cards reporting recent articles in the literature were sent to contractors working in the field, which enable them to keep up with the latest research progress.

Since then BSCP has handled a number of different subject areas. The one of interest to this group deals with the entire field of hyperbaric biomedicine and is called "The Diving Physiology and Medicine Information Service". This service searches the world's literature, selects books and scientific articles, abstracts them, selects key words and produces a set of 5 x 8 cards which are mailed out each month. Of course, one uses all of the regular services in the search: Index Medicus, Excerpta Medica, Biological Abstracts, etc., as well as library searches. All of this is now being done by the Undersea Medical Society under an ONR contract. The UMS plans to have the best collection of literature on diving problems in existence anywhere in the near future, and could well be the center for published information.

Barnard: I think that the decompression histories should become scientific diving data. I am suggesting you go to the University of Pennsylvania and also go to Dr. Shilling and the UMS. The outstanding item is this Longitudinal Health Survey.

Hempleman: I think that I have come to the conclusion that some more cooperation is needed other than is existing at the moment. That to some extent the sharing of resources is necessary. That collection of almost all data seems to me essential. As an example take the 47-synonym business of aseptic necrosis. The simple question is asked - "Does osteonecrosis have a threshold pressure?" You can only find this out by looking at your pamphlet.

Vorosmarti: I didn't think that a decompression history data bank was really necessary, but I think it is now. I think it should be used for different things than some people think it should be used for, but I think it is important.

Demodaran: From listening to the comments made over the two days, I think some very interesting points have come out. One of the things that I do think is perhaps worthwhile saying is if we looked for the situation that might exist in 20 years time we might well see the situation as a future where we have all the information stored in one bank perhaps at several levels, where your requirements feature capabilities of decompression chambers developed in activities concerned with recording information by monitoring and recording physical conditions with recorders for contributing to data banks. If you can identify and agree on common standards for information interchange that is a very significant step forward. It is interesting to note that manufacturers are supplying this kind of software even now. I think one of the things that comes out of that is perhaps to look at the various options in terms of standards for these data banking systems manufacturers are providing. Standards, for example, for describing data, standards for manipulating data and standard languages.

Gill: Are you trying to link together the various bits of the dive for one individual? I think it should be decided at a very early stage what type of results you are striving for.

Barnard: I think the aim depends on which bank you are talking about. Scientific information is dive-linked, whereas diving and medical history is diver-linked.

Ackles said it appeared to him that many people who are expressing ideas have never asked the data bank a question. I think you would find that people would be more enthusiastic about putting in their data if they had ever had the opportunity to use the output.

Kuehn: I think further that I can say what the data bank should do. I think CANDID is responsible, especially the newsletters. The questions that have been posed to the data bank have provided answers. That more than anything should convince a potential user that he should jump on board.

Barnard: Would you support the suggestion that I made that there should be a catalog of potential users, because unless you know who they are it will be difficult to circulate your newsletter?

Kuehn: Yes, I would support that as well but also I think the newsletter should be made available to others.

Ackles said researchers in different fields would ask different questions and get different answers, which could be circulated within a laboratory, making a very healthy situation for research.

Barnard: That might be useful of course when you consider the function of the UMS and their new journal. This might be a very useful input to that.

Vorosmarti: I didn't know that there were so many data banks until I got here. Nobody, or hardly anybody that is, running a data bank has ever bothered to tell anybody that they have one and that you can ask questions of it.

Harvey: Recently we put a brief report out in Pressure trying to overcome this; we will continue to do so.

Workman thought lab workers might use the banks, but they were not feasible in industry.

Edel: I would like to know if information could be translated from one computer language into another, for example, PENNDEC at the source into BASIC or FORTRAN.

Peterson commented that BASIC and FORTRAN are languages which are designed to communicate with a computer. They go through a compiler and the format of the language is translated into machine language or machine code so that this is a means of having the computer do what you want it to do. PENNDEC is a language which is designed to express a profile - a pressure profile, altitude or positive pressure, describing the important parameters about that exposure, time-depth symptoms if any, who did what when, gases breathed, and so forth. So this isn't something that can be translated into a computer language. It is something which happens to be computer-usable, but it can exist without a computer. It can exist on a piece of paper and it can be handed from one person to another.

One thing that has been of interest to me is the statement of possible reasons to have a data bank. There have been a number which fall under the category of recording past experience. Now in doing this certain things are necessary: one is format for expression, and another is an efficient means of making the recording accurate and acceptable to everyone. This seems to imply as much as possible that the recording is done by the source. I think doing this will cause the reliability of the information to increase tremendously. It will mean, however, that the person in one lab is going to have to trust people in other labs.

I'll just briefly go over the reasons for having a data bank that have been suggested at this time. Some of these have been for experimental planning, providing methods, carrying out certain experiments, avoiding repetition, redoing things that people have already done and formulating hypotheses, as with CANDID, governing their correlations between things that they have not seen before. As for evaluating parameters on established models, not everyone is interested in doing that - model testing or hypothesis testing. If you have a sufficient volume of data to work with you may be able to validate hypotheses, or at least show that it does occur. You define the problem areas and this refers more to the type of data bank that CDR Mullaly has where he has a lot of data in certain specific tables where he can pinpoint spots where there have been a lot of hits. It can be more general than that too. It can show that there are lots of hits on 500-foot or greater helium dives and that we really ought to look at that very carefully. The diver bank can provide the diver history to correlate with autopsies or other relevant information. It can in all these ways contribute to decompression schedules which is really the result that we all desire. As for your initial suggestions we agree that we need clean data. If we can say that just this much is known for sure and the rest isn't and everyone takes that into account when they get the data, then this can be considered clean data. Now as far as classifying the data, this is the problem and I agree that there are at least two classifications. The scientific chamber studies which are very accurately recorded and secondly, the commercial diving operations - open-sea dives - where things are less well defined. This certainly makes up the body of our experience and this is where our statistical information is going to come from.

Libber: I come from ONR and I am hardly an investigator. I represent a granting agency and we have the philosophical approach that our mission is to foster research in this particular area. The particular area right now under consideration is underwater physiology. We have, through the years, tried to do this and one of the ways has been to fund Dr. Shilling's abstract service.

We also are aware of the difficulties with data banks, the errors that get into the system. I think the source of effort is a big stumbling block and I think that perhaps we could collect our data in terms that would be more compatible with the computer technology in use today. This would reduce considerably the scepticism that people have about the data that is collected in these banks. I think another real big stumbling block in acceptance of these things is that people think that the very cost of the sytem is high and very little comes out of it. My feeling is perhaps the scientific community should pool its resources in this effort and concentrate on one major data bank that can serve the entire scientific community, this country and abroad as well. It is conceivable that perhaps more people could pitch in to help support this now. I don't think the Navy would want to continue supporting an international data bank at Penn on its own and I think we are looking for partners in this. It is conceivable that many people or many organizations would participate in the funding if they in turn could have a terminal located in their own laboratory. They could query the data bank to their hearts' content. We saw that people from Panamex have an international linkage system set up for their people, in Europe as well as the United States or Japan.

I think that we should address ourselves perhaps to getting some central source within our scientific community to take this thing under its wing, and I have in mind perhaps the Undersea Medical Society.

This is a professional society that represents the entire community and perhaps we should, the users and supporters, make funds available to the Undersea Medical Society which would, in turn, subcontract through a major computer center which would service the entire scientific community. I think this would be a direction for the future.

Bornmann: I will just make one comment to follow up what Dr. Libber said. We are in the business of sponsoring research. Data banks should not be looked on as an end in themselves but as an instrument to help in research and they should be measured by that standard.

Mullaly: I think we lack communication within ourselves. I found that I didn't know whether we were talking about data banks or computers. If we are talking about coming out with a decompression profile, we are talking about computing something. If we are talking about a data bank we are talking about an electronic file cabinet which has information in it. I don't think we understand what each of our data banks holds. Our purpose is to collect data on established tables and approve or disapprove their validity. We have to question some of the data we get but the only place to collect is at the site, at the time. You are going to have to trust these people to give you the best data. To do this is a matter of education and motivation. Tell them why it is important and feed them back some useful information to illustrate why it is important. You will find that the more feedback you give, the better input you will get.

Barnard: From your experience, then, would you think there is some way of stimulating the users of the existing banks to motivate them more in some way. What sort of public relations could we go through to get them to use the information already there.

Mullaly: I am trying to sell people in this meeting to see what we have and then use it before we lose it. You are not always going to be working for the same people and there are people who are going to say, "Okay, we spend so many mega-bucks a year for your program. Is it worth it and is anybody using it"? It is operational-diving oriented and we want to look at it from a safety aspect. One difficulty we run into and we're talking about is going on to build all of this data together. The Navy has tried to establish a data base on diving for about 20 years and every three or four years we back off and look at it and say, "This isn't exactly what we want. We will change it". Then three years' data is lost. The result is - we have been diving ever since 1910 - 1912 and we have only three years of data - 1970, 1971, and 1972. Now, if we suddenly say, "Let's change this", we don't have the time to change it back to a system. For instance, the truckload of files, which came under the old system from EDU, and was sent down to the Naval Safety Center, was so huge that all we could derive from it was the accidents that occurred. So we knew that we had X number of accidents in the file but no idea of how many dives were involved. So any time you change the system I think you have to really look at it and consider not only what you are going to gain but also what you are going to lose by changing the system.

Fuerle: I think that during the workshop so far we have established a real need for information among the diving community. We have gone from the point where we really weren't sure that a data bank was able to identify the kinds of things that we need. We have talked about different areas and we have come up with the fact that there are three different types of data that I think are very useful. The problem is now that you have just started the dialogue going and it is important that this kind of dialogue be continued in order to have a useful workshop. We have not established the real goals of such a data bank. This is something that ought to be accomplished. Since we have moved now from equipment and talked about real requirements and needs, the time might well be spent now to take a look, or maybe even report back at some later date, on those things which would be desirable in the system and recommend possible approaches based on the operational constraints as well as the resources available. Those resources include the available data banks, the ones represented here, along with the others that are not represented here. I think you are just at the beginning in trying to develop what we intend to do - we could develop the real concept of data bank in the future.

Hamilton: I conclude that we should send our diving logs to the data bank at Penn, our reports and reprints to Undersea Medical Society and Dr. Shilling, our divers to the Longitudinal Health Survey in Groton, and the bill to Dr. Libber! Our group is working for Ocean Systems and just from doing research for Dr. Libber uses the data bank concept. We use it for what we consider to be an outstanding success; it is the best thing we have got going for us in terms of coming up with valid decompression tables in areas that have not been explored before. There are two recommendations that I would like to make. Make the data collection in the field where it really happens. If it happens at all, it has to happen there. But that should be made as easy as possible. I want to make a formal recommendation that when a dive arrives - I am talking about decompression profiles now, dive profiles, when one arrives - that it be tagged with the basic characteristics that are included and that information be immediately put into the data bank. As a user and contributor, I think the system is working well but I think a lot of thought should be given to making it easy, especially at the free end. The person who uses it is getting at least the utility of the data which he wants as an investigator. He is in a position to wait or to work whereas for the man who has just had the experience or done the dive it should be as easy as possible for this person's data to get into the data bank.

Harvey: I have a couple of specific recommendations for the International Decompression Data Bank. I would like to see you survey potential users to find out what they think should be concentrated on in terms of data collection for the immediate future. Then I would like to see this brought up at a meeting of the International Advisory Committee so that we can be sure that the bank is oriented toward the users potentially. I would like to see the Longitudinal Health Study and the aseptic bone necrosis study which are going on as part of the Navy's program cement their relationship with the Naval Safety Center a bit better to get the diving histories of the participants in the studies better correlated with the results that are being obtained from the Longitudinal Health Study.

I should also like to see the Undersea Medical Society have a symposium or workshop to discuss the psychometric measurements that are being made. We keep talking about the data out of these banks, and type of hits and problems that divers run into. However, the measurement recording terminology and other things that are recorded in these dives need to be discussed. We need a common means of measuring and cross-exchanging our information. There is far too much variation in this and far too much difficulty in comparing data coming out.

Feld: I found this meeting very positive. One of the aspects that I think should be included in a data bank, in addition to storage, retrieval and statistics, is the computer ability. There should not be a fear of computers whether it be digital, slide rules or such. I think computers should be treated as tools to help in developing schedules.

Bardin: I have two thoughts - one has to do with people who will contribute data and it is our experience that it is an extremely painful job. It is a tiresome kind of job to enter data. We have tried to make it as easy as possible but no matter how it is going to be done it is going to require an investment of time and energy because it is just a very hard thing to get important facts into the data bank. The other suggestion is that the people who publish in the area should turn their information over to the International Decompression Data Bank. I wonder whether the granting agencies would, perhaps, consider part of the job they would like done when they give a grant for somebody to do diving research to be to stipulate what data would go into the International Decompression Data Bank.

Kenyon: One subject that I would like to touch on is what is the law going to require in terms of records. It is possible the diving industry is going to get slapped with a particular standard system. Secondly, if funding should stop what will be the cost? Maybe in a market survey we could get a general idea of cost to the user. Also, we need a standard input form.

Harvey: The data bank at Penn has a very nice key field system for finding dives within their bank. It would lend itself ideally both at Naval Safety Center and for recording key information from various dives. I recommend a discussion of the 150 saturation dives that are down there in terms of some means of finding those for researchers who would like to examine a specific dive for the specific purposes allocated to this kind of research.

Young: I am delighted with the two banks that have been agreed upon. I would agree also that the general medical one, although necessary, is probably too much of a problem just at present.

Harvey: In the Longitudinal Health Study on submariners and divers we have found some very interesting things about mass screening of people in terms of automation, such as automated blood-pressure recording. I would hope that each of you who are interested in data banking will look at this as a potential application or at least a pilot study in terms of studying divers over the long haul.

Kuehn: I would like to make the recommendation again that the International Decompression Data Bank submit a newsletter to the potential users as well as current users to the program.

Shilling: The UMS has a quarterly newsletter, Pressure, which will welcome contributions.

Barnard: I was thinking we can recommend a newsletter; I don't think we can recommend who should produce it. I think this is open to discussion. I don't think I should specify Pressure; that is an Undersea Medical Society function. We are a UMS workshop and we ought to tell them that we think that there should be information in the form of a newsletter.

Kuehn: I would like to make one further point. It is very expensive so far for all data banks to come to their current stage. I think all will admit that they have ideas they will use. If we are to implement further changes and progressive ideas in data banking we should incorporate all the current prospective users' requirements. I think people who have any inclination ever to use data banks should jump in and request current ones to further guide them in the instructions to the next stage of development. If that doesn't happen I can see these things failing in time.

Harvey: If any of you have further thoughts after this meeting or things that seem pertinent to data banking, forward them to me or send them to Dr. Ackles, Miss Kronheim or Dr. Lambertsen for further review and we will try to get it summarized in some form of general publication.

Miller: I support what they said. The only thing is I think in whatever newsletter we use we should put out what is available, a format that could be used, and what you get out of it. The kinds of examples that we are talking about. I think once people realize what they have to do to interrogate the bank and what they get out of it after they do is very useful.

The question of legal responsibility for data in the bank was discussed by Miller, Peterson, Barnard and Libber and a legal opinion was recommended. If you are going to set anything up as a data bank, or as a source of data on diving and other related subjects, you should scrutinize the organization as you are basing your future work on its permanence. It is important to look at how your organization is financed and supported in this respect.

Parker: I certainly concur with the conclusions that have been made but I would make a strong pitch for two things. Number one is that these various data banks talk to each other. I think that is most important; otherwise they are going their separate ways and there may be some duplication and perhaps other things which are undesirable. Each could profit from the mistakes of the others. The other is the commonality among the data banks such that when you get something out of it from one bank you don't have to design a whole new course to find out what is coming from the other one.

Adams: As a potential user of data banks from the medical history aspect, I hope you will continue to consider it may be quite complicated. In answering the long-term problems, one set of histories is going to be mandatory.

Hempleman: I think it is an appropriate time to offer some congratulations to those who have already contributed their material in this field in supplying data which has been used for years in bibliographic source work. I think that every person who has worked at my laboratory has used these source books and I think that this is the time to say, "Thank you very much" to Dr. Shilling, where all this work has been done and also to the people who support it.

Harvey: I think it would be very nice if each of the banks would concentrate on letting potential users know exactly how to use them.

Peterson: To start the communication process, I have Xeroxed papers which indicate the data banks that we have right now and also some of the information that we hope to get in the not too distant future, too.

Barnard: There has been feedback, so now we are talking of trying to persuade people to put raw data into the International Data Bank and attempting to compel people to send literature to Dr. Shilling and the thing I am still not quite certain about in my own mind is the future of a medical data bank. There are steps that can be taken by the U.S. Navy within its own confines. There are things we can do in the Royal Navy within our own confines. It may be possible in the future to set up some degree of cooperation but I don't foresee at the moment any possibility of sharing this information. The concept of the data bank is a way of storing data in such a manner that regardless of what you do with it you can have access to it. In other words, the structure of the data bank doesn't restrict the sort of inquiry that you can make of it. Therefore, in some respects the idea of splitting it up into several groups is rather irrelevant. Though we may be forced initially to think in terms of several banks, there is a possibility in the future of coming down to one true data bank.

Bornmann: I'd like to comment on the very useful relationship between the Undersea Medical Society and the Navy. In this series of workshops we have selected topics in underwater research which have specific time limits for the Office of Naval Research and NMR&DC. What we wanted to do was to have these topics discussed by small groups of participants representing a mixture of selected underwater personnel and outside experts in parallel disciplines and I think this meeting has been a very great success from that point of view. The sessions have been of great value to me and I believe also to Dr. Libber and I saw things also of value to the Undersea Medical Society, which we had not planned on, but I am glad to see them. The utility of this will be pointed up more when we get the printed proceedings of this workshop.