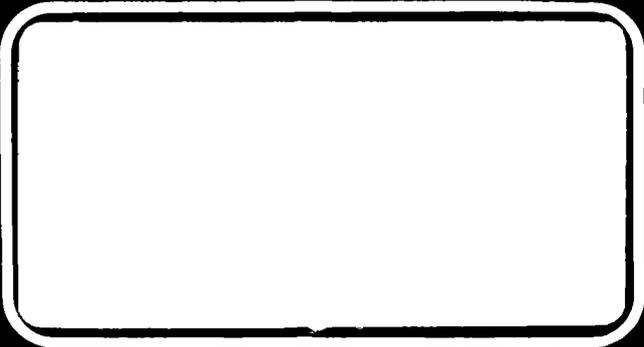


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FOURTH CANADIAN DIVING SYMPOSIUM

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DEPARTMENT OF NATIONAL DEFENCE - CANADA

(6)
THE FOURTH CANADIAN DIVING SYMPOSIUM (4th)

HELD AT

THE DEFENCE AND CIVIL INSTITUTE OF ENVIRONMENTAL MEDICINE,

TORONTO, ONTARIO,

24-25 OCTOBER, 1979

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THE TOPICS OF THIS SYMPOSIUM ARE LISTED AS FOLLOWS

AGENDA

FOURTH CANADIAN DIVING SYMPOSIUM

Wednesday, 24 October, 1979

Welcome and Opening Remarks

Dr. R.W. Heggie, DCIEM
LCdr B. Ridgewell, DCIEM

Phase I XDC-2 Validation Dives
0-54 msw.

Lt Kooner RN
DCIEM

➤ An Overview of DCIEM Research and
Development in Support of Canadian
Diving Operations.

Dr. L. Kuehn, DCIEM

➤ Time Lapse Photography as an Adjunct
to Diver and Underwater Vehicle
Observations.

Dr. C. Schafer
Atlantic Geosciences
Centre

➤ Report on Canadian Underwater Industry.

Mr. R. Fortier
Department Industry
Trade and Commerce

➤ In situ Structural Repairs to Ships
in the High Arctic.

Mr. J. English
Can-Dive Services Ltd.

➤ Outlook for Oil and Gas in Canada's
Offshore Frontiers.

Dr. J. Hea
Department Energy, Mines
and Resources

➤ Canada's Energy Resources.

Mr. S. MacKay
Imperial Oil Ltd.

➤ Technical Aspects Involved in a Year
Round Study of Kelp Growth and
Physiology in the Canadian High Arctic.

Mr. F. Watts
Dalhousie University

Tour of Deep Diving Facility

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Thursday, 25 October, 1979

- | | |
|---|--|
| ➤ Man Underwater, Medicine and Miracles - II ; | Dr. M. Lepawsky,
Vancouver, B.C. |
| ➤ Occupational Centre for Occupational Health and Safety ; | Mr. J. King
Winnipeg, Man. |
| ➤ DCIEM Diving Programme ; | LCdr B. Ridgewell, DCIEM |
| ➤ Diving Incidents - Tobermory ; | Dr. G. Harpur
Tobermory, Ont |
| ➤ A Review of the Uses and Developments in Remotely Operated Underwater Work Vehicles ; | Mr. D. Huntington
International Submarine
Engineering Ltd. |
| ➤ U.S.N. Changeover Mk V to Mk XII ; | Lt(N) M. Coulombe
NEDU |
| ➤ C.U.T.C. Training | Mr. J. Fortin
Canadian Underwater
Training Centre |
| Hyperbaric Facilities | Dr. J. Kerr
Toronto General Hospital |

PHASE I XDC-2 COMPUTER VALIDATION DIVES
0 - 54 MSW

By

M.D. Kooner

ABSTRACT

The Canadian Forces have used decompression computers for a number of years. However, advances in electronics have allowed the older analogue computers (Mk VI) to be replaced by more sophisticated digital electronic computers (XDC-2's) which monitor the diver's depth and calculate the safe depth in real time.

An operation lasting four weeks ⁽¹⁾ was conducted at DCIEM utilizing the newly acquired Deep Diving Facility as the vehicle to test the operational diving envelope of the XDC-2 Decompression Computer at 36-54 msw. Ultrasonic Doppler monitoring techniques were used throughout the series of dives to measure bubble activity in the pulmonary artery. ⁽²⁾ ⁽³⁾

The initial results would seem to elucidate the XDC-2 computer envelope by adding more information and more clearly defining the present calculated operational curves. As it was necessary to find a new reference point between the calculated curves, the Royal Navy Limiting Line as published in the R.N. Diving Manual (BR 2806) Table Eleven, was introduced as a datum line. It was found that there was a degree of correlation between the R.N. Limiting Line and that of the XDC-2 recalculated operational envelopes. Doppler ultrasonic monitoring results confirmed the severity of a dive and it was possible to grade a dive as mild, moderate or severe.

INTRODUCTION

A series of air dives were carried out in the Deep Diving Facility (19 Jun 79 - 13 Jul 79) to determine the safe operational envelope of the XDC-2 Decompression Computer to a maximum simulated depth of 54 metres of sea water.

The predicted envelope is shown in Figure 1, and was reproduced as a result of a large number of chamber dives over the past ten years using versions of the Kidd-Stubbs decompression model for decompression control. (4)

The following graph depicts the predicted diving envelope. The various boxes depict the number of decompression incidences within that area. The outer curve (solid) was calculated to show a 10% bends incidence, and the middle curve (broken) a 3% bends incidence, while the inner curve (broken) shows nil decompression.

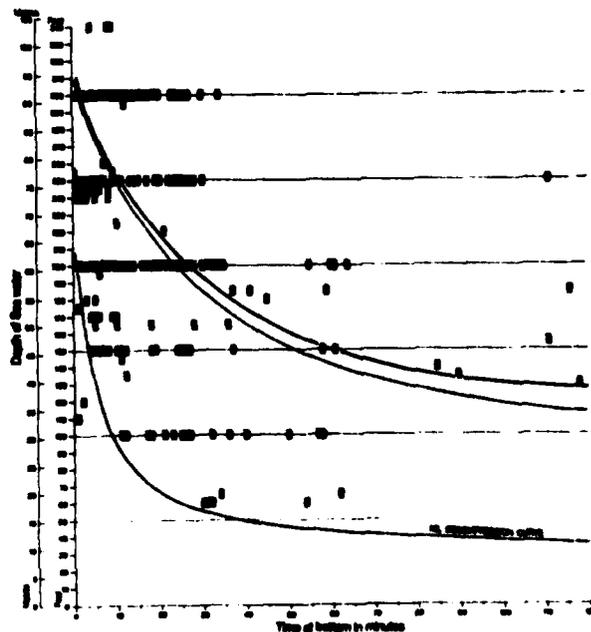


Fig. 1. XDC-2 (Predicted) Operational Envelope

BACKGROUND

The DCIEM Decompression Computer (4,5) is used for the safe decompression of divers by monitoring the actual depth-time history of a dive and calculating and displaying the safe depth for optimum decompression. In the past, the computer was used successfully in the form of a pneumatic analogue computer. With recent developments in electronics, it has become possible to replace such analogue computers with miniature digital electronic computers which monitor the diver's depth and calculates the safe ascent depth in real-time.

The XDC-2 Digital Decompression Monitor was designed for DCIEM on contract by CTF Systems Incorporated.(6) The advantage of a digital computer such as the XDC-2 is that it requires a minimum of calibration and maintenance. Because the safe ascent depth is calculated mathematically and is presented on the digital display, it is possible to follow the safe depth exactly during decompression.

The objective of the present series of dives (1) was to evaluate the XDC-2 for operational diving, to determine whether the safe depth as displayed can be followed exactly for safe decompression, and to define the operational limits for its use. The basic dive profile was descent at a rate of 18 metres of seawater (msw) per minute to depth, and remaining at that depth for the required time; initial ascent was at 18 msw/min to the calculated safe depth, continuous ascent following the safe depth to 3 msw, a stop at 3 msw until the computer indicated that surfacing was possible, and then ascent to the surface. See Figures 2, 3).

The DCIEM decompression calculation model has been determined by carrying out a large number of man-dives. The model itself consists of four compartments in series with the same depth-dependent supersaturation ratio applied to all compartments. Under certain conditions, for deep dives or long bottom times, the model gives decompression profiles which become inordinately long at the shallow depths when the third and fourth compartments become the controlling compartments for decompression.(7) The maximum bottom times, which are intended to define the operational limits for the present dive series, have been selected so that the third and fourth compartments are not controlling the decompression. Several bottom times leading toward the maximum bottom time were tested for each depth.

In order to assist in the evaluation of the dive profiles as generated by the XDC-2 and to determine their relative safety or to determine whether any modifications need to be made in the future, the divers were monitored for bubbles in the pulmonary artery with the Doppler Ultrasonic Bubble Detector. Dry divers were monitored periodically during the decompression phase in the chamber. On the surface after decompression, both dry and wet divers were monitored periodically for several hours.

JUNE, 1979

4	M	T	W	T	F	M	T	W	T	F
CALENDAR DATE	18	19	20	21	22	25	26	27	28	29
DIVE DAY		1	2	3	4	5	6	7	8	9
DIVING PERSONNEL										
R								C		
K				A						
M						C				A
O			B		C		D		E	
F								E		
LA		C				A				E
MA				C				A		
J.			S		S		S		S	
R		A				E				C
N										
MA		F		B						S
PA						S		S		F
MAT			C		F		E		B	
L			D		E		F		A	
F			E		B		A		D	
S.			F		A		B		C	
G										
LE			A		D		C		F	
C		S				B				
PC		B				D		F		
E				S		F				
SU				E						D
KE		E		D						
SK										
NO		D						B		
ME				F				D		B
CR										
		B Team	A Team	B Team						

DIVING SUBJECTS SCHEDULE

Dive Position Legend

- A - Wet Diver #1
- B - Wet Diver #2
- C - Attendant #1
- D - Attendant #2
- E - Dry Subject #1
- F - Dry Subject #2
- S - Spare Subject

TABLE I

Diver, Diver Position and Date of Dive

JULY, 1979

DIVING SUBJECT SCHEDULE

Dive Position Legend

- A - Wet Diver #1
- B - Wet Diver #2
- C - Attendant #1
- D - Attendant #2
- E - Dry Subject #1
- F - Dry Subject #2
- S - Spare Subject

	T	W	T	F	M	T	W	T	F
CALENDAR DATE	3	4	5	6	9	10	11	12	13
DIVE DAY	10	11	12	13	14	15	16	17	18
<u>Diving Personnel</u>									
R		A							
K				C				D	
MI						E			
O	F		A		B		C		D
FU		D		S					
LA						B			
MAN		C				F			
J	S		S		S		S		S
RE				B				E	
N									
MAC		E		A					
PA						S		A	
MAT	A		D		C		F		E
LE	B		C		D		E		F
FO	C		F		E		B		A
SAB	D		E		F		A		B
G									
LES	E		B		A		D		C
CL		F				C		S	
PO									
EA		S		D					
SU				F					
KE						A		F	
SK									
NO				E				C	
MED		B							
CR						D		B	
	A Team	B Team	A Team						

TABLE I (Continued)

TEAM CONCEPT

There were basically two teams of subjects, A and B Team. "A" Team consisted of four divers from the Fleet Diving Unit (Pacific) and two CEDD members. They remained as a team throughout the exercise and dived every other day. "B" Team dived on alternate days but did not maintain its integrity as a team; its composition varied and was dependent upon the availability of potential subjects. "A" Team was strictly military clearance divers. "B" Team was made up of military clearance divers, ships divers and civilian ships divers.

Basically, "A" Team was controlled inasmuch as the same personnel were used throughout the exercise, although they did rotate positions for each dive. "B" Team changed its composition for each dive and therefore more variables were introduced.

EXECUTION

The dive schedule is shown in Table II.

DIVE SCHEDULETABLE II

<u>DATE</u>	<u>DIVE DAY</u>	<u>SERIAL</u>	
18 Jun	Preparation Day		
19 Jun	1	A	(36 msw for 50 min)
20 Jun	2	B	(36 msw for 55 min)
21 Jun	3	B	(36 msw for 55 min)
22 Jun	4	C	(36 msw for 60 min)
25 Jun	5	C	(36 msw for 60 min)
26 Jun	6	D	(45 msw for 35 min)
27 Jun	7	D	(45 msw for 35 min)
28 Jun	8	E	(45 msw for 40 min)
29 Jun	9	E	(45 msw for 40 min)
3 Jul	10	F	(45 msw for 45 min)
4 Jul	11	F	(45 msw for 45 min)
5 Jul	12	G	(54 msw for 25 min)
6 Jul	13	G	(54 msw for 25 min)
9 Jul	14	H	(54 msw for 30 min)
10 Jul	15	H	(54 msw for 30 min)
11 Jul	16	J	(54 msw for 35 min)
12 Jul	17	J	(54 msw for 35 min)
13 Jul	18	A	(36 msw for 50 min)

Table III depicts the Dive Serial letter as described in Table I. and was used in conjunction with Annexes of the Protocol as published for this particular exercise.⁽¹⁾

TABLE III
DIVE TIMES FOR XDC-2 COMPUTER

DIVE SERIAL	DEPTH (msw)	BOTTOM TIME (min)	ASCENT TIME TO 3 msw (min)	STOP TIME AT 3 msw (min)	TOTAL ASCENT TIME (min)	TOTAL TIME OF DIVE (min)
A	36	50	22	31	55	105
B	36	55	24	37	63	118
C	36	60	26	43	71	131
D	45	35	26	29	57	92
E	45	40	29	37	68	108
F	45	45	32	45	79	124
G	54	25	27	24	53	78
H	54	30	31	35	68	98
J	54	35	37	45	84	119

Descent time to bottom is included in the bottom time. Descent rate varies from 18 msw/min to 8.8 msw/min at 54 msw for the dive chamber and transfer sphere combination. Descent time to 36 msw is 2.5 min.; to 45 msw is 3.3 min.; to 54 msw is 4.2 min. The profiles were generated on the above times.

The times and depth were a calculation of Figure 1. and the intention was to stay on the cautious side of the 3% decompression sickness line.

Descent and Ascent profiles for Dive Chamber / Transfer Sphere combination

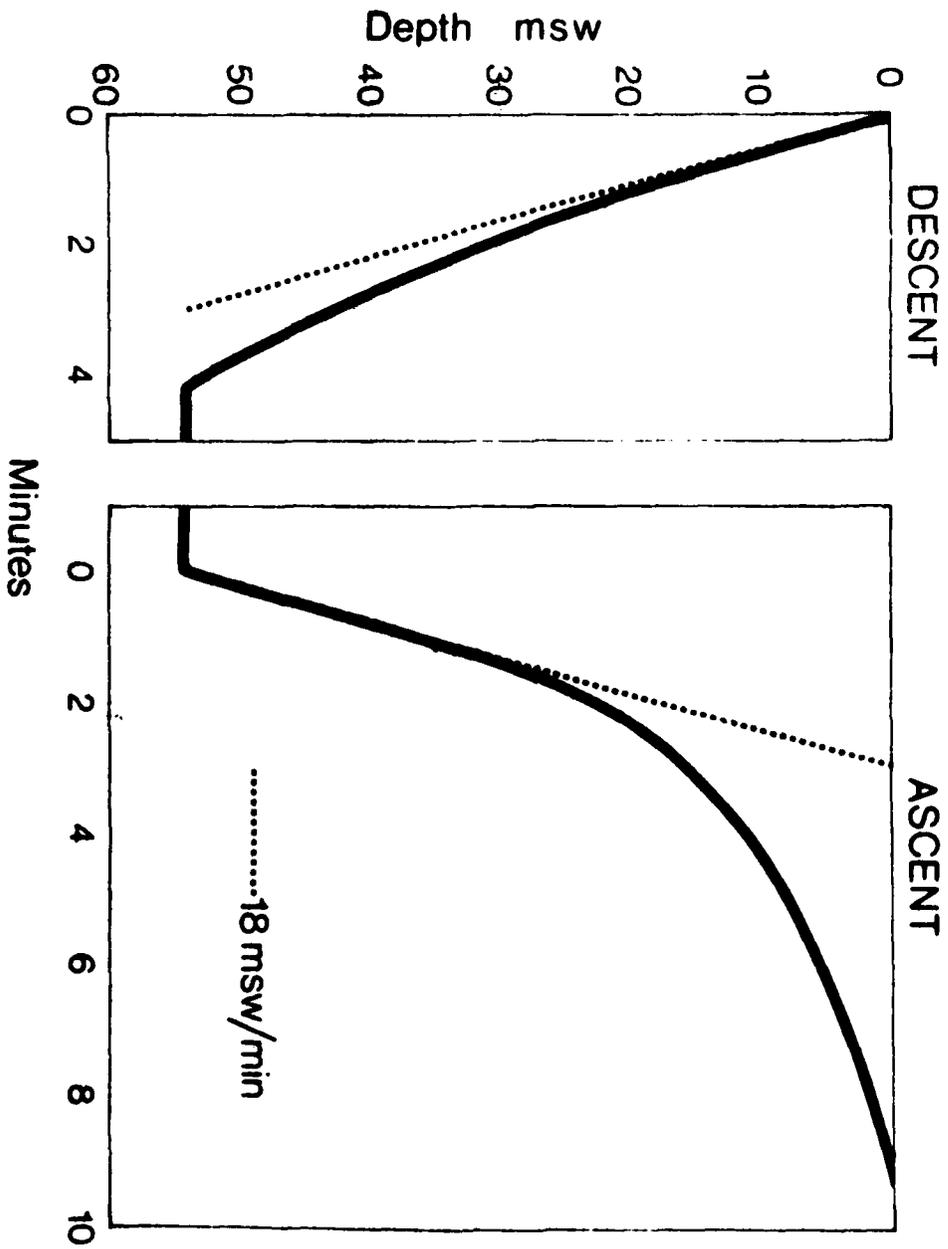
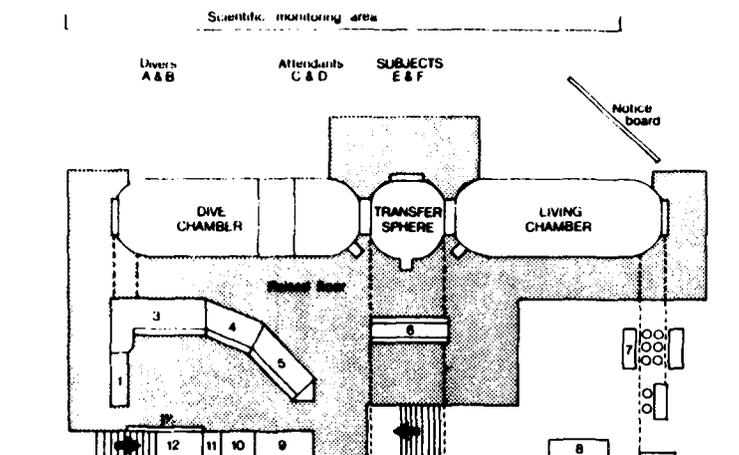


FIGURE 2.

Figure 3. DDF Layout



This picture shows part of the Deep Diving Facility Layout

- No. 1,3,4,5 - the Main Control Console
- No. 6 - the Secondary or Emergency Control Console
- No. 7 - the Environmental Loop Equipments
- No. 8 - the Oxygen Room
- No. 9,10,11,12 - the Main Engineering Room, the 'Pit' for potable water, fire suppression and Purifier.

The two dry subjects (E and F) in the Transfer Sphere remained at rest except for Doppler Monitoring. The two dry tenders (C and D) were carrying out moderate workloads.

The two wet divers (A and B) alternated on an underwater ergometer, with a workload of 50 Watts set. Wet suits and KMB-9 diving equipment were utilized.

Figure 4. - Typical Bubble Activity Observed

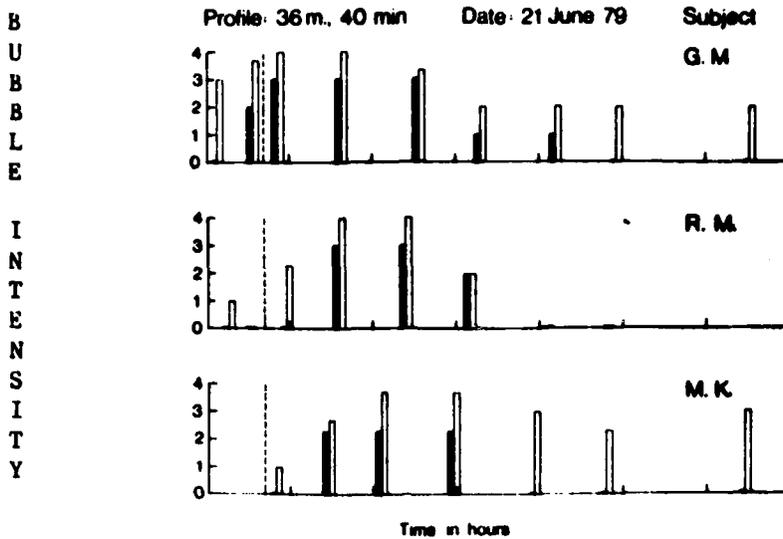


Figure 5. shows the type of doppler results obtained for each of the dives in the series. During decompression, bubble counts were observed at specific times indicative of internal decompression stress provoked by silent bubbles which on reaching certain levels of the KM or Spencer Codes were seen to culminate in cases of Type I bends.

Analysis is now in progress to quantify the number of bends with/vs profile and the usefulness of doppler techniques in correlation with the observed results, which will form a separate report.

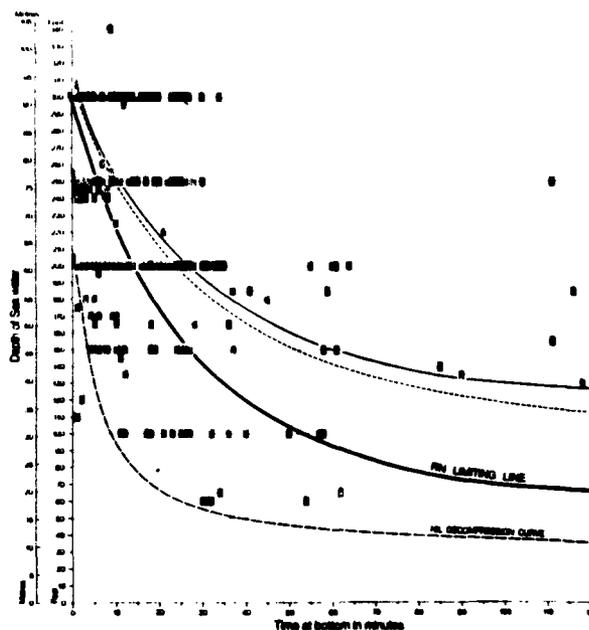
The Y axis is based on the Kisman-Masurel scale⁽²⁾. On this scale, ultrasonic doppler monitoring measures the frequency, duration and amplitude of bubbles in the venous blood stream. The 0-4 is a code which defines the bubble intensity of a dive.

The X axis is purely a function of time.

The white bars depict bubble activity with exercise whereas the solid bars represent bubble activity without exercise.

As a result of cases of unacceptable decompression sickness problems, caused in part by the high exercise level of the affected subjects, the entire schedule was revised to re-introduce the R.N. Limiting Line as shown in Table II of BR 2806.⁽⁸⁾ The resultant superimposed limits are shown in Figure 1. (revised)

Figure 1 (Revised) - XDC-2 Operational Envelope



The Kidd-Subbs Model testing had historically involved quiescent non-working divers and therefore the effect of exercise on bubble formation is suspected of being the prime reason for the cases of decompression sickness recorded.

As a result of the above incidents, the dive schedule was radically altered (Table II):

Table II (revised)

DIVE SCHEDULE

<u>DATE</u>	<u>DIVE DAY</u>	<u>SERIAL</u>	
18 Jun - Mon	Preparation Day		
19 Jun - Tue	1	C	(36 msw for 50 min)
20 Jun - Wed	2		(cancelled)
21 Jun - Thu	3	B	(36 msw for 40 min)
22 Jun - Fri	4	B	(36 msw for 40 min)
<hr/>			
25 Jun - Mon	5	A	(36 msw for 30 min)
26 Jun - Tue	6	A	(36 msw for 30 min)
27 Jun - Wed	7	D	(45 msw for 20 min)
28 Jun - Thu	8	F	(45 msw for 30 min)
29 Jun - Fri	9	E	(45 msw for 25 min)
<hr/>			
3 Jul - Tue	10	E	(45 msw for 25 min)
4 Jul - Wed	11	F	(45 msw for 30 min)
5 Jul - Thu	12	C	(36 msw for 50 min on O ₂ for decompression)
6 Jul - Fri	13	G	(54 msw for 15 min)
<hr/>			
9 Jul - Mon	14	H	(54 msw for 20 min)
10 Jul - Tue	15	H	(54 msw for 20 min)
11 Jul - Wed	16	J	(54 msw for 25 min)
12 Jul - Thu	17	J	(54 msw for 25 min)
13 Jul - Fri	18	G	(54 msw for 15 min)

TABLE III (Revised)

DIVE TIMES FOR XDC-2 COMPUTERS

DIVE SERIAL	DEPTH (msw)	BOTTOM TIME (min) ⁽¹⁾	ASCENT TIME TO 3 msw (min) ⁽²⁾	STOP TIME AT 3 msw (min)	TOTAL ASCENT TIME (min)	TOTAL TIME OF DIVE (min)
A	36	30	14	15	31	61
B	36	40	18	20	40	80
C	36	50	22	31	55	105
D	45	20	15	14	31	51
E	45	25	19	16	37	62
F	45	30	22	21	45	75
G	54	15	16	13	31	46
H	54	20	22	16	40	60
J	54	25	27	24	53	78

Descent time to bottom is included in bottom time. Descent rate varies from 18 msw/min to 8.8 msw/min at 54 msw for dive chamber and transfer sphere combination. Descent time to 36 msw is 2.5 min.; to 45 msw is 3.3 min.; to 54 msw is 4.2 min.

Ascent time is initially at 18 msw/min to 40 msw and is then determined by the maximum venting capability of the dive chamber/transfer sphere combination.

WEEKLY ANALYSISWeek 1 Day 1 to Week 4 Day 18

This week commenced with a 50% incidence of bends when diving at 36m for 50 minutes. It quickly established that the estimated 3% bends incidence curve was too far right and doppler monitoring gave a very early indication that the dive was excessively stressful.

The following day was spent treating patients from the first dive and all subjects had a completely successful recovery.

Dive Day 3 - (Dive#2) - was established using the R.N. Limiting Line as laid down in BR 2806, Table Eleven and was for 36m (40 min). Doppler indicated a stressful dive.

Dive Day 4 - (Dive #3) - Once again doppler indicated a stressful dive (one type 1 incident occurred) but with a marked reduction in bubble activity. This indicated that the R.N. Limiting Line and the doppler grading were complementary.

Week 2

The next two days, Dive Day 5 and 6 (Dive #4 and #5), were used to establish a low doppler bubble activity level and this was achieved at 36m for 30 minutes. A clean series of dives were reported, however, one subject (a dry tender) "spiked" with bubble activity, had a sharp pain in his chest and then a full recovery.

By Dive Day 7 (Dive #6) the depth was increased to 45m with a bottom time of 20 minutes. This position was chosen as it was five minutes less than the R.N. Limiting Line and coincided with the RNPL Limiting Line.

This particular dive was clean, the bubble activity being mild in intensity.

The next day, Dive Day 8 (Dive#7), it was decided to increase the bottom time by 10 minutes, 5 minutes over the R.N. Limit Line; the bubble activity was moderate and one subject suffered a similar sensation to that experienced the previous Monday with a spike in doppler bubble activity coupled with a pain in his right shoulder.

This incident coupled with the one of a few days previous, and commensurate with past dives at DCIEM, pointed to "dry tenders" suffering decompression sickness. The only common denominator was that the attendants were working during the decompression phase and immediately after surfacing, albeit not arduously, but nonetheless, more so than the wet divers, or the other two dry subjects.

The following day, dive day 9 (Dive #8), the bottom time was reduced to 25 minutes in accordance with the R.N. Limit Line. On surfacing, the subjects remained in the DDF area at complete rest, except for doppler monitoring for 30 minutes and the tenders were instructed to slow down with their workloads.

Week 3

Dive Day 10 (Dive #9) which was 45m for 25 minutes, showed a drop in bubble activity and a clear dive was recorded.

Dive Day 11 (Dive #10) was a repeat of Dive Day 8 (Dive #7) and the same procedures were followed. However, one subject reported sick during that evening and was compressed to 18.3m and owing to symptoms (suspected Type II), was treated on an extended Table 6. A complete recovery was recorded. This particular subject who is 47 years of age and overweight, was a previous patient on Dive #1 and his previous 24-hour history revealed that he had had no sleep and a slight head cold. His past 24 hours disposition was not accurately recorded prior to the dive.

Dive Day 12 (Dive #11) was originally planned as a 36 msw for 20 minutes dive, but owing to the mildness experienced in the previous dive (deeper and same bottom time) it was argued that little meaningful data would be gleaned; therefore, a special dive was introduced. This entailed a repeat of Dive #1, 36 msw for 50 minutes; however, all subjects switched to O₂ at 10 msw during the decompression phase; the object of this dive was to determine the difference in doppler bubble activity using O₂ for future phases, and was not really a part of Phase I.

The interesting point of comparison is that there was no bubble activity which was drastically different from Day 1 which showed a severe dive. This significantly showed that doppler readings could monitor and show the difference.

Dive Day 13 (Dive #12) returned to the original schedule once again. The depth was increased to 54 msw. The bottom time was 15 minutes and all subjects except for one showed little or no bubble activity. The one subject who did bubble subsequently suffered a mild form of decompression sickness and was treated on Table 5. This was an interesting case and there is no doubt that the subject had two strikes against him. In the first place, he was fatigued after a very stressful week, and secondly, he was moving far too much as a tender. These views are, of course, very subjective because the author was that subject.

Dive Day 14 (Dive #13) was an increase of 5 minutes bottom time over dive day 13 and passed without incident, although the doppler monitoring team assessed the dive as being of a stressful nature.

Dive day 15 (Dive #14) - This was a repeat of that of the previous day's dive of 54 msw for 20 mins., and a moderate to severe bubble activity was observed.

Dive Day 16 (Dive #15) - This was suspected to be of a stressful nature considering the previous results obtained at 20 mins. bottom time with this depth. The doppler indicated that this dive which was 25 mins. at 54 msw, was graded moderate.

Dive day 17 (Dive #16) - This was a repeat of the dive of the previous day and doppler indicated this as a severe dive. Although there were no confirmed cases of decompression sickness, post-dive grilling revealed that one or two subjects were suffering from "niggles" and one subject did have a transient pain.

Dive day 18 (Dive #17) - This was a repeat of a previous dive of 54 msw for 15 mins. This was graded as a mild dive.

TABLE IV - SUMMARY

<u>DAY NO.</u>	<u>DEPTH</u>	<u>TIME AT BOTTOM</u>	<u>NO. OF DIVERS</u>	<u>DOPPLER SEVERITY</u>	<u>COMMENTS</u>	<u>TEAM</u>
1	36m	50	6	Severe	50% bends incidence	B
2	Cancelled - Treatment of three Type I cases of decompression sickness for Day #1.					
3	36m	40	6	Moderate to Severe		B
4	36m	40	6	Moderate	1 Type I incident	A
5	36m	30	6	Moderate		B
6	36m	30	6	Mild to Moderate		A
7	45m	20	6	Mild		B
8	45m	30	6	Moderate	1 Type I	A
9	45m	25	6	Mild		B
10	45m	25	6	Mild		A
11	45m	30	6	Mild to Moderate	1 Type II incident	B
12	36m	50	6	Mild	O ₂ from 10m	A
13	54m	15	6	Mild	1 Type I incident	B
14	54m	20	6	Mild to Moderate		A
15	54m	20	6	Moderate to Severe		B
16	54m	25	6	Moderate		A
17	54m	25	6	Severe		B
18	54m	15	6	Mild		A

NOTE:

Grading of a particular dive was based on the number of divers experience grade 3 at rest on the KM scale, out of the total number of divers participating in a particular dive. As an operational guideline Kisman suggested the following grade be used:

0 - mild	Zero	Divers from six = mild
1 - mild/moderate	One	Diver from six = mild/moderate
2 - moderate	Two	Divers from six = moderate
3 - moderate/severe	Three	Divers from six = moderate/severe
4 - Severe	Four	Divers from six = severe
5 - Severe	Five	Divers from six = severe
6 - Severe	Six	Divers from six = severe

CONCLUSION

The initial results are very encouraging and should lead to a better understanding of the XDC-2 operation envelope. An interesting correlation between the R.N. Table Eleven Limiting Line as published in BR 2806 and our own results became apparent. Doppler correlation with incidence of bends was observed and the grading of dives would appear to present us with a safer approach to table validation in the future.

Subjects were suspected of not reporting "niggles", a trait of the diver, and Team "A" would appear to have built up an immunity to stressful dives, as their doppler bubble activity and bends incidence were less than those of "B" Team.

RECOMMENDATIONS

1. That a further series of dives be planned in order to obtain more information.
2. That Canada in conjunction with U.K., U.S.A. and France, re-examine the doppler monitoring techniques as perfected by Kisman and Masurel.⁽³⁾
3. That air tables in the 36-54 msw range be examined for safer profiles thereby obviating the necessity of the dive supervisor introducing his own safety factor while conducting operational dives within this range.
4. That the use of oxygen during decompression should be investigated in an effort to safely extend bottom times particularly at the deeper depths.

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AN OVERVIEW OF
DCIEM RESEARCH AND DEVELOPMENT
IN SUPPORT OF CANADIAN DIVING OPERATIONS

by

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Historically, diving research has been a primary interest at DCIEM since the early design work on the Kidd-Stubbs decompression computer model at the beginning of the last decade (21). Since that time, this research effort has been expanded in quantity and quality so that it is now one of the major research themes at the Institute. The recent establishment of the Deep Diving Facility (DDF) has provided both a research focus point and a vehicle for conduct of deep hyperbaric experiments.

It is the intent of this paper to describe an overview of the progress attained in a number of given diving research areas at DCIEM throughout the last decade and to concentrate specifically on recent progress since the last Canadian Diving Conference held at DCIEM in 1978. Although biomedical research in support of Canadian Forces diving operations is conducted throughout the Institute's four research and development divisions, it is primarily concentrated in the Biosciences and Diving Divisions.

One of the classic problems limiting the deployment of divers in operational diving is the requirement for decompression. In 1976, the Canadian research history in decompression computer technology was summarized in a report (13) that reviewed the development of pneumatic and electronic analogue decompression computers which continuously take into account the diver's actual pressure-time history and automatically calculate his safe ascent depth. All analogue computers, either pneumatic or electronic, suffer from extensive calibration and maintenance requirements and, for that reason, DCIEM developed digital microprocessor-based decompression computers that can be used for in-water monitoring as well as in-chamber experiments. Since the decompression model is implemented in software in the computer, a more realistic and sophisticated model of the human body can be used than is possible with analogue computation. Maintenance and calibration requirements are considerably reduced and the packaging is flexible, permitting either diver-carried or surface-supported modes.

In the 1976 report, specific mention was made of the XDC-1 desk-top keyboard decompression computer which could be used in accelerated time for dive planning and scheduling, as well as for real-time monitoring of chamber dives and surface-supported operational

dives. This has been followed by the XDC-2 decompression monitor (28, 30) which is a panel-mounted real-time instrument for regulation of decompression of surface-supported tethered divers or for hyperbaric chambers. It is the operational version of the XDC-1 and it can operate from line A.C., a 12-volt automobile battery or from internal rechargeable nickel-cadmium batteries. The internal batteries ensure that the decompression history of a diver is retained if the external power source fails, a feature absent on the XDC-1. The XDC-2 decompression monitor is presently being adopted for operational diving by the Canadian Forces to depths as great as 90 msw. In addition, its operational envelope has been and is presently being assessed experimentally in a project by Major I. Buckingham, who has done similar work with the U.S. Navy Experimental Diving Unit while on an exchange posting. This project also involved evaluation of the XDC-2 decompression profiles by real- and post-time Doppler ultrasonic monitoring about which more will be said later in this report.

Several prototypes of a microprocessor-based diver-carried decompression computer, the XDC-3, were developed and tested in 1978. The main body of the instrument is contained in a small package mounted on the diver's gas tanks with a free-floating display cylinder connected to it via a short umbilical cord. The pressure input to the computer is accomplished via a solid-state National Semiconductors transducer built into an oil-filled compartment in the electronics package, which is designed to be temperature-independent. The display unit uses light-emitting diodes to show actual depth, safe depth, elapsed time and nil decompression time/ascent time back to the surface. An inertial switch in the display unit activates the display for six seconds whenever a reading is desired; however, there is a continuous indication of the diver's depth status by an array of green, yellow and red light-emitting diodes. The entire prototype is powered by four 9-volt alkaline or rechargeable batteries which is adequate for four hours use. The computer contains a low power CMOS microprocessor to conserve power which will be replaced by CMOS EPROMs in later models. At present the XDC-3 decompression computer is being adapted to the sports diving market by a Canadian Company, Kybernetics Inc., who hope to market an adaption of it called the Cyberdiver sometime in 1979.

The foregoing XDC series of digital decompression computers have been developed on contract from DCIEM by CTF Systems, Inc. of Port Coquitlam, British Columbia over the last five years. All embody the Kidd-Stubbs decompression model (21) but they are not limited to this particular theory; the inherent decompression algorithm can be updated or changed completely by replacement of the PROMs in any particular unit. This feature was demonstrated in a recent report (29) in which the success of a modified XDC-3 computer was favourably compared to a U.S. Navy diver portable computer (7) on shallow-water decompression trials. At present, an XDC-4 decompression management system (32) is under development as a general purpose decompression computer to permit dive planning, data logging, real-time diver monitoring, profile

generation and program modification. Since the decompression programs are stored on floppy discs, it is model "independent" although it is presently programmed for use with helium, nitrogen and neon breathing mixtures. It has its own decompression control language and will be used on laboratory or field dive monitoring tasks once it is at DCIEM, hopefully in 1979.

The computerized decompression data bank known as CANDID has been improved and extended since its development early in 1973 (12). It is being transferred from the PDP-9 computer system on which it was first developed to the faster and more versatile PDP-1140 and PDP-1170 systems. Its primary function in the last years has been to provide a depth-time-at-bottom analysis of the success of the Kidd-Stubbs decompression model in preventing decompression sickness.

Concern for the provision of safe decompression profiles for operational diving has followed not only the "black box" approach of decompression computers but also the real-time monitoring of bubble incidence in divers with ultrasonics (8, 9, 10) with particular emphasis on various Doppler techniques and on the use of the second harmonic of a through-tissue ultrasonic transmission system.

Although the latter more complex research-oriented approach may eventually be applicable to bubble detection in either tissue or the bloodstream of divers, it is the former Doppler technique that has the greatest amount of interest from diving medical authorities. In this technique ultrasonic energy is sent in pulsed form from a transducer positioned over the precordial region of the chest into the heart and pulmonary artery of the diver. Some of the energy is back-scattered to the transducer but it is shifted in frequency (the so-called Doppler shift) according to the speed of blood flowing through the artery. Any bubbles in the blood stream moving through the pulmonary artery are easily detected by their unique sound.

The Doppler ultrasonic detection of bubbles involves instrumentation which provides an acoustic signal which can be recorded on a tape recorder and monitored with headphones. Grading of the bubble signal aurally is presently the only useful way to monitor bubbles in divers although a signal processor is under development at DCIEM which will automatically perform this function. Thus, although the current Doppler technique is quite easy to use in the field, its greatest limitation is that a skilled operator is required to interpret bubble signals from background noise. Such bubble gradation is performed according to a code developed by Merrill Spencer of the Institute of Applied Medicine and Physiology in Seattle. In this code, the bubbles are graded on a simple scale of 0 (no bubbles) to 4 (bubbles too numerous to count).

Such Doppler techniques as these have been used by DCIEM personnel to evaluate the severity of decompression stress on saturation dives conducted in France as well as subsaturation dives recently performed in the Deep Diving Facility for validation of the use of the XDC-2 decompression computers.

Basic research has been initiated into the etiology of inner ear decompression sickness, using squirrel monkeys (27) as animal subjects. The monkeys with inner ear "hits" show severe fibro-osseous labyrinthitis in their semi-circular canals, often to the point of occlusion of their perilymphatic and endolymphatic spaces. Different stages of bubble formation have been observed in the temporal bones of these animals. Continued work is being concentrated on audiological tests of the experimental animals and on the incidence of isobaric decompression sickness in the inner ear.

Theoretical work of effects of mixed gas usage on diver decompression has continued during the last three years with the formulation of a model for inert gas transport in the human body (33). This work is being extended to gas diffusion studies pertinent to use of the mass spectrometer with biological subject matter.

A second classical problem limiting the deployment of divers in operational diving is that of thermal distress, usually in the form of hypothermia, although hyperthermia is occasionally a problem in rapid compression of bells and in long surface pre-dive waiting periods for fully-suited divers. Collaborative projects with the U.S. Navy Experimental Diving Unit (18, 24, 25, 26) have been concerned with the establishment of the rate of heat loss from unclad divers in helium-oxygen gaseous environments as part of a program to determine the dangers of cold stress and the temperature/time relationship tolerated by divers in cold diving bells or in hyperbaric chambers in which environmental conditions are uncontrolled. The latter project concerned the evaluation of hot-water supplied suits in providing thermal comfort to divers at depths ranging from surface conditions to 1400 fsw.

During the last year, research in this area was concerned with the establishment of thermal exposure limits for divers in cold water (14, 16), not only for laboratory experimentation but also in operational diving. The use of cheap disposable temperature-radio pills (1, 19) in conjunction with a portable battery-powered hand-held temperature-radio receiver is recommended for application to all working environments for monitoring of diver core temperature on the surface (or in a bell) before and after dives. This technology has also recently been extended to the measurement of skin temperatures of active subjects through the development of skin-mounted tabs or plates (6) glued to the skin. Both techniques reduce the complexity of diver thermal monitoring in the laboratory and in the field.

Heat loss to cold water has also been assessed calorimetrically at DCIEM in several basic research investigations. The calorimeter used is that formerly employed by Craig (4) in his researches; it has now been established at DCIEM (15). One project (20) has culminated in the finding that consumption of ethanol does not increase the rate of heat loss from humans in cold water, as has been hitherto accepted. Another project has been the determination of the effect of the cooling rate upon the tolerance and thermal responses of mildly hypothermic men (3), which has resulted in the determination of 300 kcal as the maximal amount of voluntary heat loss in a cold water environment. The calorimeter has also been used to assess physiological thermal insulation of several long-distance swimmers prior to their attempts at swimming across Lake Ontario.

Various aspects of diver performance have been investigated at DCIEM during the last decade, notably in the area of inert gas narcosis. This work has been continued during the last two years involving collaborative work with York University (5). This work has been concerned so far with the effects of inert gas narcosis on the functions of mental perception, the short-term memory store and the long-term memory store. Of greater concern now are problems emanating from sleep dysfunction. Much of the concern with diver performance has been directed to the practical problems associated with the human engineering of divers tools. Several studies pertinent to this subject are in progress at DCIEM.

During the early part of 1979, a large multidisciplinary experiment called Chamber Experimental Test and Protocol Evaluation (CETPE) was conducted in the DCIEM Deep Diving Facility (DDF) to determine the effectiveness of the pertinent human factors engineering in ensuring subject health and well-being as well as the effectiveness of the scientific data channels in conveying data to and from the subjects. CETPE also provided an opportunity for training of DCIEM watches and chamber operators in the use of the DDF sub-systems as well as for operational appraisal of their effectiveness. It was a seven-day one-atmosphere "dive" run exactly in the same fashion as will be the first pressurized DDF saturation man-experiment. Four diving subjects selected from the scientific, engineering and diving disciplines participated in the experiment and were subjected to a variety of biophysical, psychomotor and human factor tests, both in the dry and wet modes, from which baseline data was obtained for control use in subsequent hyperbaric experimentation. The evaluation was a success in virtually all aspects and it has established the groundwork for the first pressurized saturation and non-saturation human experiments in the DDF (2).

From the DCIEM research program, as has been presented so far in this paper, there have come various new items of diver technology which is now being introduced into the commercial and military diving marketplaces. The history of the DCIEM diving computers has been

detailed earlier in which the commercialization of the XDC computer series was documented. It is hoped that the temperature-radio pill technology will also proceed to the marketplace; two Canadian companies are endeavouring to do this in 1979. Several new diver navigation devices have been proposed. One is a peripheral horizon device⁽¹⁷⁾ for allocation inside a diver's mask or helmet to display to him, via light-emitting diodes, his orientation with respect to the gravity vector and the true horizon. Another is a stereo-audio compass⁽²³⁾ for navigation in dark or deep waters. In this device, directional signals perceived from a small towed body are conveyed in sonic pulses to either side of diver's head, thereby providing him with directional information through a sense that is not often employed in the free-swimming underwater environment. Besides directional information, this device senses and displays audibly the sideways drift of a diver, his true directional heading and his accumulated underwater distance travelled.

A new respiratory heat exchanger (11, 22) for reclamation of diver respiratory heat loss has been developed and may be commercialized later in 1980. In addition, a new form of diving suit insulation⁽³¹⁾ has been developed, based on the vacuum principle; further contractual work is necessary to improve the human factors of the suit before it is suitable for operational diving.

As has been detailed above, the spectrum of research and development activities at DCIEM pertinent to diving range from the very basic to the very applied areas of endeavour. Several unique features of DCIEM have been instrumental in the success of these efforts. One is the multi-disciplinary aspect of the team and group research prevalent at the Institute. Another is the long tradition of *diving interest* that began with the early mechanical decompression computers and culminated with the establishment of the DDF. Yet another is the healthy interchange of ideas through the auspices of various organized meetings, of which the Canadian Diving Symposium can be said to be a good example.

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TIME-LAPSE PHOTOGRAPHY AS AN ADJUNCT
TO DIVER AND UNDERWATER VEHICLE OBSERVATIONS

By

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ABSTRACT

Underwater observations that are made using divers, submersibles or cable-controlled vehicles are usually time-limited because of safety and/or cost considerations. Consequently, the needs of scientific projects that depend on these resources have dictated the development (and use) of a suite of in situ monitoring devices in marine research that includes underwater time-lapse photography and video systems. The output obtained from these systems can "bridge the gap" between successive time-limited observations enabling the identification of events and processes that are worthy of detailed investigation or manipulation using diving teams and underwater vehicles.

Underwater time-lapse systems must be configured to cope with a variety of environmentally-related problems. For example, nearshore marine environments are highly variable in terms of wave activity, biological productivity, and in bottom community structure. These factors often produce changes in the suspended matter concentration of bottom waters. Therefore light systems must be capable of a range of power outputs in order to maintain a constant level of exposure. Support frame configurations must permit the positioning of camera and light source to minimize the effect of light scatter between the camera and the subject. Lens and light fouling by algae and burial of the support frame by sand waves are common problems that must be considered in nearshore monitoring situations. In deeper waters (+200 m) additional problems arise because of the increased length of monitoring periods that are usually desired in these less variable and less accessible environments. Logistics often require that time-lapse systems remain unattended for periods of weeks to months. In continental slope environments (300 to 500 m), potential problems include sediment slumping that may displace or bury the system, shifting of the support frame because of the activity of bioturbating organisms, or of bottom currents that may erode the substrate around the frame base, and possible bombardment by cobbles and boulders in areas of rapid iceberg melting. In deep environments the support frame also provides a desirable substrate for certain epifauna that can attach themselves at locations that obstruct a portion of the field of view. These attached species and the system itself may attract other forms that can disturb the subject area under observation.

Time-lapse video systems are especially useful in nearshore environments where the immediate playback feature provides information that can be helpful in making mid-course modifications to field experiments or, for example, changing the method of disposal of dredge spoil at a dump site. Video systems are inexpensive and flexible but have low resolution higher power requirements compared to film cameras for underwater applications. The video camera must be positioned to maximize detail at the scale of interest, usually with attendant reduction in field of view dimensions. For deep water applications time-lapse photography is the norm. At the Bedford Institute of Oceanography the most recently developed tool for monitoring aspects of the marine environment is called "RALPH". RALPH is designed to observe the dynamics of sediments and benthic organisms at continental shelf depths. The system contains an electromagnetic current sensor, an upward-looking sonar for wave and tide measurements, conductivity and temperature probes, and a super 8 mm camera and prototype flash unit. A microprocessor is used to control the sampling rate of all sensors and to log numerical data on a cassette recorder for a period of up to two months.

REPORT ON CANADIAN UNDERWATER INDUSTRIES

by

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Department of Industry, Trade and Commerce

1. The paper was introduced by providing a general discussion of the mandate of the Department of Industry, Trade and Commerce and Ocean Industries in particular. The study undertaken by a consultant for the Department on Canadian Underwater Industries in Canada was discussed and details were provided later in the paper. This report was presented to update the information provided at the 1978 meeting on the above points and provide results from the study.

2. In addition, information was provided on task force activities and sector profile which were undertaken by Ocean Industries Division as part of the total departmental effort.

3. The latest Industry, Trade and Commerce activities have included a preparation of an industrial strategy for presentation to the new Government Economics Board. The highlights of the strategy produced by Ocean Industries covers Canadian content and plans for research and development assistance. This was discussed in generalities only and the attendees were advised that any specific information required could be obtained by contacting Ocean Industries, Ottawa.

4. The general activities of Canadian Ocean Industries were then discussed. The indication of increased activity was an increase in sales from \$180 million in 1976 to \$300 million in 1978. The offshore activities in 1979 provided approximately a \$450 million market. This is a positive indication of the growth in this field which is presently underway. Some details were then provided on the activities in the domestic market as follows:

a. Panarctic activities in the Arctic Islands

Gas discoveries here have proven threshold reserves for exploitation;

b. Panarctic - Arctic Pilot Project

This project is in a fairly advanced status indicated by a recent contract placed for gas turbines and generators of a value of approximately \$17 million;

c. Dome Beaufort Sea

Four drill ships were active in 1979 including the Arctic 4 icebreaker; advance exploration and production decisions are expected to be taken in the very near future;

d. Newfound-Labrador

Seven companies are active in this area including nine drilling and 26 supply vessels. Thirteen holes were planned for 1979 at an estimated cost of \$250 billion;

e. Sable Island - Mobil

Gas discoveries here are indicated by a commitment of \$50 million for an appraisal program.

5. The study which was commissioned by Industry, Trade and Commerce on Canadian underwater industry activities was discussed. The study was co-funded by the Newfoundland Department of Industrial Development and the attendees were informed that the Newfoundland Department of Industrial Development requested that any specific information required on this study should be requested from them for release.

6. The domestic market only was addressed in this study due to the problems of time and funding, and it is the intent of Ocean Industries to cover the international market in the future.

7. The terms of reference were generally read out and addendum No. 1 covering information requested on diving specifically was discussed.

8. The list of respondents who provided information on the report were as follows:

- a. Atlantic Marine and Diving Company Limited, Fredericton, New Brunswick;
- b. Can-Dive Services Limited, Vancouver, B.C.;
- c. Horton Maritime Exploration Limited, Vancouver, B.C.;
- d. Huntec 70 Limited, Toronto, Ontario;
- e. International Submarine Engineering Limited, Port Moody, B.C.;
- f. Lockheed Petroleum Services Limited, Vancouver, B.C.;

- g. McLaren Marex Incorporated, Dartmouth, N.S.;
- h. Norco Limited, Saint Johns, Newfoundland;
- j. Alistair Resource Management Limited, Calgary, Alta.

9. The summary of results, conclusions and recommended actions were then discussed and slides were shown as follows:

- a. Figure 1 - Offshore Canada Activity;
- b. Table 1 - Forecast of Offshore Petroleum Exploration Activities;
- c. Table 2 - Forecast Delineation and Development Activities;
- d. Table 3 - Potential Canadian Market - Diving Equipment and Services;
- e. Table 4 - Underwater Vehicles and Services;
- f. Table 5 - Underwater Production Equipment and Services;
- g. Table 6 - Geophysical and Oceanographic Survey Equipment and Services;
- h. Table 7 - Underwater Communication, Navigation and Instrumentation.

10. A brief discussion took place to describe some of the recent developments of our Canadian Ocean Industries and these included: Horton Maritime Exploration Ltd.'s Ben Franklin Submarine Programme, Huntco 70 Ltd.'s Deep Towed System Program, LPS's Frontier Production Pilot Project, and a report on International Hydrodynamics Company Limited receivership status.

IN SITU STRUCTURAL REPAIRS TO SHIPS

IN THE HIGH ARCTIC

By

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Can-Dive Services Ltd.

INTRODUCTION

Over the last four years an intensive and wide ranging exploration program has been underway in the Beaufort Sea. To support this, Dome Petroleum - Canadian Marine Drilling operation, Can-Dive Services Ltd. has been providing an equally intensive and wide ranging diving service.

To date, over 1100 dives have been made using the five bell systems and various surface diving equipment maintained on location. The tasks undertaken vary from routine inspection to complex rigging and repairs. Work has been completed under the full range of arctic conditions, both winter and summer.

The purpose of this brief discussion is to describe two unique and challenging projects which were completed this season. This involved extensive underwater ship repairs and hyperbaric wet and dry welding on the drilling vessel, Explorer III and the government owned/Can Mar leased ice-breaker, John A. MacDonald.

HULL REPAIRS - JOHN A. MACDONALD

Survey and Temporary Repair

On November 25, 1978, the C.C.G. ice-breaker, John A. MacDonald, reported damaged hull plating as a result of encounters with heavy ice during it's end of season operations. An emergency call was put in to Can-Dive Services Ltd., North Vancouver, and an inspection team was dispatched to the location. Inspection began on November 26, 1978.

Inspection dives revealed the presence of damaged hull plate over an area approximately 5 feet square, with cracked and torn plating (1.75 inch thick) at it's centre in an irregular pattern. Internal inspection showed similar plate damage as well as damage to several of the ships stringers and frames.

The decision was made to custom fabricate a temporary patch exterior to the hull, to be welded in place by the diving team. Additional crew and equipment were dispatched from Vancouver and arrived on site within 10 hours of the first call.

A small, 8 x 8 x 3 ft. deep, habitat was fabricated from scrap material on site in Summers Harbour and fitted over the damaged area. A seal was made between the hull and habitat using rubber gaskets and turn buckles. The habitat was then de-watered and divers entered to commence fitting of the patch.

The irregular shape of the damage necessitated fabrication in several pieces (1/2 in. M.S. plate), which were welded individually in place after being formed to fit.

The temporary patch was completed and habitat removed after a total of 24 dives during which 70 man-hours were spent welding and fitting the patch. A full inspection was made on the damaged areas and the repair deemed adequate by the certifying agencies to allow the vessel to remain unattended during the winter months.

Phase I was completed ten days after receipt of the first emergency call.

PHASE II - PERMANENT REPAIR

Planning

Due to the nature of the damage and the necessity of using the ice-breaker early in the season to free up the drilling vessels, the decision was made to effect a permanent ships repair, on location prior to the initial break-up in June of 1979.

The repair project was headed by Can Mar Engineers and involved the Canadian Coast Guard, Purvis Navcon Shipyards, Burrard Yarrows Corp., Can-Dive Services Ltd., and various certifying and testing agencies.

Following complete internal damage assessment, a plan was initiated whereby a large, watertight cofferdam would be fitted over the damaged area; a large section of hull plate would be removed; damaged internal structures removed; a pre-formed and cut replacement section fitted and welded in place; internal structures replaced; and cofferdam removed, following complete inspection and testing of the repair.

Can-Dive was tasked with the responsibility for the design, construction and installation of the cofferdam structure. Burrard Yarrows fabricated the replacement structures and Purvis Navcon was responsible for all internal and dry welding.

Construction

Inspections revealed that a replacement plate, 8 ft. x 11 ft. of 1-7/8 in. Grade E plate was required to replace the damaged area. The cofferdam was designed to accommodate this size, with sufficient

clearance to allow ready access to the riggers and welders. The final structure was 20 ft. x 15 ft. by approximately 4 ft. deep, with a net displacement of 1200 cu. ft. The dry weight of the assembled structure was 9 tons.

The structure was fabricated in two main sections (compatible with Hercules Transport), with removable side and base plates to allow adjustment to the ship's contours which could be expected to vary from those provided by Burrard-Yarrows due to local irregularities in the hull plate. The design and construction took place at Can-Dive's North Vancouver base over a period of three weeks.

On-Site Preparation

The first major task on site was the set-up of the diving station on the ice and subsequent removal of the ice in the immediate vicinity of the damage to allow placement of the cofferdam. Ice thickness over the site varied between 3-5 feet. In addition, the entire hull of the vessel was sheathed in an ice layer varying from 1 foot to 18 inches thick (a normal condition after the winter season). Divers commenced removal of the ice using a "ditch witch" for surface ice and hydraulic chain saws and a steam jet for the hull ice. As usual, the chain saws proved to be the most effective removal tool. Over a 4-day period, commencing May 3, 1979, divers and support crews removed an estimated 60 tons of ice and full access to the work site was achieved. Surface conditions, although clear for the most part, stayed at -20°C .

Following a final survey of the damage, locator pins were put through the hull, from the inside, to provide the necessary reference points for positioning the cofferdam.

Installation

Installation commenced on May 9th, following completion of the final surface assembly of the unit. It was hung from pad-eyes welded above water to the ship's hull and sucked into rough position utilizing comalongs secured to pad-eyes wet welded in place by the divers.

The position of the cofferdam was adjusted as required and divers commenced welding on the primary pad-eyes and support braces for the final fit. The contours of the adjustable sections were checked and marked for final installation.

On completion of measurements the structure was removed for final assembly of the sealing surfaces and side plates. While surface work continued on this, divers continued to locate and weld the necessary pad-eyes to the ship's hull.

The cofferdam was re-positioned late on May 12, and a final seal and de-watering achieved on May 13. The structure was monitored over a

short period for small leaks and Purvis Navcon welders commenced fitting the plate shortly afterwards.

Repair

The repair procedure to internal structure was commenced on May 3, 1979. External work within the cofferdam commenced May 14, 1979. The damaged hull plate was removed, cut to exact size to fit the replacement plate. The replacement plate, weighing approximately 7000 lbs. was lowered into position and pulled into place from inside the ship. Welding began immediately to complete the root pass and restore the hull's integrity. Welding of the plate was conducted on a 24-hour basis and was finally completed on June 4, 1979. The entire repair was fully tested and certified prior to removal of the cofferdam.

Demobilization

Removal of the cofferdam commenced on June 3 and was completed June 4, 1979. All pad-eyes, braces and rigging points welded on by the divers were removed and a final video inspection made to satisfy the certifying agencies of the hull condition.

In excess of 80 man-hours bottom time was expended over the 10-day installation period. During this time six additional inspection dives were made on the ship's props and other vessels in the area. Removal required only 4 man-hours. The entire operation was completed utilizing a 5-man diving team with no incidents or serious problems.

During the welding phase of the John A. MacDonald repair, work was commenced on a more complex structural repair to the drillship, Explorer III, which is described in the next section of this discussion.

STRUT REPAIRS - DRILLSHIP EXPLORER III

Survey

In August, 1978, a complete hull inspection of the Explorer III was conducted to meet the requirements of Det Norske Veritas for recertification of the vessel. During the inspection of the port stern tube and prop support strut and hub, divers discovered a large crack running the length of the hub at a point where the diagonal support strut was welded to the hub casting.

After a thorough cleaning, detailed inspection showed that the crack, initiated in the aft edge of the strut in the weld zone, had propagated down into the hub casting approximately half-way long its length. A second crack ran from the forward edge of the strut in a similar fashion. The two cracks did not appear to link in the centre area. No other structural damage, other than normal corrosion, was found on either the diagonal or horizontal struts.

As a result of the damage report, the port prop was secured and the vessel restricted to operation with only one prop and the assistance of service tugs for the remainder of the season. This condition did not affect the drilling operation in any way, but would result in considerable delay in relocation of the vessel.

Repair Alternatives

A permanent repair to this structural failure was determined to be essential to restoring the vessel to full operational capability for re-certification.

Discussion was commenced on the repair alternatives available, which included:

- a. terminating operations and travelling to drydock in the south;
- b. in situ repair by construction of a temporary drydock;
- c. in situ repair by hyperbaric welding.

The removal of the vessel from operation for southern drydocking would involve the loss of the ship for the remainder of the 1978 season and the majority of the 1979 season. It would also necessitate the support of the John A. MacDonald which would affect the entire drilling operation.

The decision was made to make repairs in situ, utilizing the temporary drydock or hyperbaric welding alternatives. Can-Dive Services was requested to provide a detailed proposal for the hyperbaric repair, outlining the procedures, inspection methods, timing and costs. Can-Dive was also involved in the discussions concerning the use of the temporary drydock as this method would also involve extensive diving operations.

Repair Procedure

The hyperbaric repair method was selected by Can Mar Engineers, based on time and cost-effectiveness. The programme was designed for flexibility regards the repairs required, since the full extent of damage to the internal structural member of the strut would not be known until removal of the external cheek plates and full N.D.T. inspection.

- a. Habitat Design - Construction

The welding and testing was to be achieved in a dry hyperbaric environment created by the installation of a welding habitat fitted around the shaft, hub

and struts of the vessel. The habitat was fabricated of steel in three sections to allow installation and ease of handling.

The habitat was sized and configured to seal at four points on the ship's structure, these being the stern tube; the rope guard and the horizontal and diagonal struts. The points of sealing also served as bearing points to hold the eight x eight x eight foot structure in place.

A full size mock-up of the strut - hub - shaft assembly of the vessel was fabricated in our North Vancouver shop to guarantee proper fit and allow for set-up of the welding and life support equipment in optimum location.

The habitat was equipped with a continuous air ventilation system located to provide efficient clearing of smoke and fumes during welding operations. Lights, air tools and welding equipment were positioned on wall brackets for ease of access.

Life support equipment was set up for convenience of use, comfort and safety.

A dual BIBS system was utilized. One system provided air to the specially built welding masks which were light weight and equipped with welding shields and, demand and free flow supplies. The overboard dump feature of the mask was by-passed for this operation since the habitat was an air environment and not inert gas purged. (a requirement for deep water operations).

The bail-out BIBS were set up to allow rapid exit of the habitat in an emergency.

A complete communications and video monitoring system was also installed to allow continuous taping/monitoring of the operation.

Welding Equipment

Welding equipment installed in the habitat included the following:

- a. pre-heat/post heat elements and control/monitoring circuitry;

- b. TIG-Argon shield equipment (root pass);
- c. MIG-C25 shield wire feed (cover pass);
- d. standard stick welding equipment
- e. arc-air gouging equipment;
- f. pneumatic chippers/grinders.

All electrical circuits were ground fault protected to insure safe operation. The wire feed unit was custom housed and argon purged. Rods and welding wire were stored in special containers to preserve proper welding characteristics. The amount of equipment stored in the habitat was minimized for safety and comfort.

All welding equipment, rods, wire and procedures were approved by Det Norske Veritas and Lloyd's Register as being suitable for the repairs required and the steel grades involved.

Personnel

A six-man diving team was assigned to this project. The two senior diver/welders (Ron Jager - Rick Wassick) were both fully certified and experienced in hyperbaric welding. Prior to commencement of the job both attended an extensive six-week refresher course in Nelson, B.C.

Non-Destructive Testing

Non-destructive testing and pre-post heat requirements were specified by Det Norske Veritas. Can-Dive provided the necessary equipment and housings to conduct the required tests.

Can-Dive also provided a licensed Non-Destructive Testing Radiographer/Diver and Senior Radiographer for certification and interpretations through Stasuk Testing of Vancouver. Test required included:

- a. magnetic particl inspection;
- b. ultrasonic thickness and flow detection;
- c. gama-ray radiograph.

The Planned Repair Procedure

The prop support struts were fabricated of three structural members - the two outer cheek plates and the central core plate. The damage was visible only on the outer cheek plate, but there was concern

that the central core plate and hub-casting could also have been damaged. The repair procedure was designed to allow full assessment of the damage by sequential removal of the cheek plates; non-destructive testing of the suspect members; remedial work as necessary and replacement of the damaged sections.

The planned sequence of events for the repair is outlined as follows:

1. Clear ice from ship's hull and surrounding area for clear access;
2. Install habitat;
3. Locate required pad-eyes and rigging to support the weight of the stern tube, hub and prop to insure that shaft alignment is maintained. Alignment was monitored continuously throughout the project by metering and feeler gauges. The buoyancy of the habitat was taken into consideration in determination of the support required. Talbot Jackson Associates were retained by Can-Dive to provide the information on the prop support and possible heat effects on the Simplex seal and bearings during welding operations.
4. De-water habitat and re-check alignment prior to commencement of work;
5. Clean and prepare damaged area for detailed inspection (visual and NDT) to determine the extent of the cracks.
6. Remove inner cheek plate to effect repair to the core plate lower side. Removal done via grinding and arc-air gouging.
7. Determine extent of crack (if any) on inner core. If crack is a simple fracture and limited to the core plate only - crack to be gouged out for welding.
8. Commence pre-heat and welding of core plate.
9. In the event the crack continues in to the hub casting or is of compound nature, the outer cheek plate may have to be removed to effect repairs to the core from both sides.

10. Prepare the strut for refit of the prefabricated replacement inner cheek plate.
11. Perform complete inspection and NDT of new weld repair to core plate.
12. Place and weld inner cheek plate replacement.
13. Perform complete inspection and NDT of new weld repair to cheek plate.
14. Repeat the above procedures on the outer cheek plate.
15. Perform final NDT to all new weld repair prior to removal of the habitat. Alignment and shaft movement monitored continuously during the repair operation.

All welding operations to be conducted on a 24-hour basis until completion of the job.

Operations

Diving operations commenced May 20, 1979 on the 4-6 ft. ice cover. Weather was generally clear with surface temperatures between -10 and 0°C.

Five days were required to remove the ice using hydraulic chain saws and high pressure steam. Up to ten feet of ice was found in the area between the stern tube and hull.

The habitat installation commenced on May 25 and was completed May 31. One set back to the operation was the failure of the L.P. compressor which contaminated the habitat and equipment with oil, and required three days to clean up before welding operations could commence.

Preliminary inspection and NDT work commenced June 1 and was completed June 3. Tests revealed the presence of surface cracking in the hub casting in addition to the large crack visible in previous inspections. The inner cheek plate was removed as scheduled and the core plate was found to be cracked. Repairs were commenced as scheduled, following the sequence outlined in the previous section. Diving commenced as scheduled, following the sequence outlined in the previous section. Diving commenced on a 24-hour a day basis. At one point during the work, the diver welders worked continuous shifts in the habitat in excess of eleven hours each.

During the welding procedure, no variations in shaft alignment were experienced. All welds met or exceeded specifications and the repair was completed on schedule.

The ice removal phase of the operation was completed in 13 dives, spanning 5 days and 34 man-hours.

The habitat/equipment installation, including time lost to complete clean-up after oil contamination, was completed in twelve dives over a six-day period and 42 man-hours.

The actual welding, repair and testing phase of the operation took place over a 15-day period during which 55 dives were made for a total of 297 man-hours. The total on site project, with its six-man crew spanned 26 working days, eighty dives and 373 man-hours in the water and habitat.

Follow-up

The Explorer III was certified for operations for the 1979 season and has been operating all season with full use of both props. Periodic ultrasonic inspections are made to monitor the condition of the hub, and all results have been positive.

Summary

The successful completion of these two major projects in ice covered arctic waters has demonstrated conclusively that permanent structural repairs can be made on location, utilizing relatively mobile and portable equipment.

The significant advantage of this type of repair is that no operational time was lost on either vessel, and the '79 drilling season commenced on schedule. Had it been necessary to send the vessels to southern drydock, the Explorer III would have missed part of the 1978 season and the start of the 1979 season. The John A. MacDonald, due to the late date the damage occurred, would have missed the entire '79 season, seriously affecting movements of the Can Mar fleet.

Habitat-hyperbaric welding and the use of temporary cofferdams for ship repairs are not new techniques. The fact that these techniques have now been successfully utilized in ice covered arctic waters is truly significant and unique and are expected to see wider application in the future.

OUTLOOK FOR OIL AND GAS IN CANADA'S OFFSHORE FRONTIERSByDr. James P. HeaDepartment of Energy, Mines and Resources

Canada is committed to a policy of oil self-sufficiency in the coming decade. At present we produce 1.8 million B/D and import 420,000 B/D. The forecast for the producibility of western Canadian crude oil shows a decline to about 1.3 million B/D in 1990 and including the production from synthetic oil plants indicates a shortfall of about 600,000 B/D which will have to be met by additional oil sand plants, heavy oil upgrading plants, frontier oils and conservation, and to the degree of these failing, by imports from the Middle East and Venezuela. Let us briefly review our crude oil supply by reserves categories.

1. Conventional Oil and Gas

Light and medium crude oil and natural gas liquids from Western Canada are expected to decline from 1.33 to 0.69 million barrels per day by 1990. This National Energy Board forecast includes production from existing fields and new discoveries. The figure is quite conservative and from the geological assessment of the resource base undertaken by the Federal Department of Energy, Mines and Resources it is likely that if there is adequate drilling in western Canada that additional conventional oil and gas will continue to be found, such as recently at West Pembina and in the Deep Basin of Alberta and British Columbia. Remaining established conventional oil reserves are about 5.6 billion barrels, but probable recoverable reserves are over 8 billion barrels at a likelihood of 50 per cent.

A major challenge is in the enhanced recovery of oil from reservoirs. The best reservoirs, such as in the thick and porous carbonate fields of Alberta can recover up to about 70 per cent of the oil in-place by primary and waterflood recovery. In the poorer reservoirs, especially tight sandstones, the primary recovery is usually 10-15 per cent and the recovery through waterflooding is usually less than 35 per cent. Primary recovery means that the dissolved gas in the oil provides the drive mechanism to push the oil into the well bore while in waterflooding, water is injected in some wells and the oil is produced in recovery wells. Enhanced recovery uses thermal methods, such as combustion in the reservoir and steam injection and gas or chemical flooding to recover more oil. Much research and field testing is currently underway to find the best method suited to the many types of oil fields. However, the costs are high and the methods require many years to prove out for individual fields.

2. Heavy Oil

Heavy oil is a viscous and high density oil used mainly to make asphalt. It is produced in wells at low rates and has to be mixed with natural gas liquids to be moved by pipeline. Canada produces about 200,000 B/D of heavy oil, about half of which is exported to the United States.

The major region where there are large reserves of heavy oil is at Lloydminster on both sides of the Alberta-Saskatchewan border. Reserves are estimated to be 20-35 billion barrels in-place of which 5-10 per cent are recoverable by primary methods, 10-15 per cent by waterflooding and 25-40 per cent by thermal and steam injection methods.

Two upgrading plants, each of 50-100,000 B/D capacity have been proposed in the Lloydminster area to crack the heavy oil by coking and adding hydrogen to make synthetic oil. These plants and additional plants will provide a significant amount of new oil, but the technology of enhanced recovery and upgrading are not yet proven in commercial application.

3. Oil Sands

Oil sands from the deposits of Athabasca, Wabasca, Cold Lake and Peace River in Alberta contain nearly one trillion barrels of crude bitumen in-place at shallow depths. Bitumen is a viscous mixture of heavy hydrocarbons containing sulphur which cannot be recovered at economic rates through well bores. The bitumen has to be recovered by mining or by steam injection which lowers its viscosity enough to be produced through wells.

There are two open pit mining and bitumen upgrading plants in operation north of Fort McMurray in Alberta: Great Canadian Oil Sands which came on stream in 1967, produces 45-50,000 B/D and is undergoing a 12,500 B/D expansion to be completed in 1981 and Syncrude which came on stream in 1978 with a rated capacity of 100,000 B/D and with a planned expansion to 200,000 B/D by 1990. A third mining project, Alsands of Shell Oil is projected to produce 140,000 B/D by 1986.

The Cold Lake project by Esso Resources will involve the drilling of thousands of wells and steam injection. The method used called 'Huff' N' Puff' whereby steam is injected into the reservoir for several weeks and the heated bitumen is then produced through the same well bore. The project is expected to be on stream by 1986 and to produce 140,000 B/D. A longer term project by Petro-Canada will involve the drilling of wells with recovery through electric pre-heating and steam injection with a planned capacity of 100,000 B/D by 1990 and 200,000 B/D by 1992.

The bitumen recovered is made into synthetic oil by coking and hydrogenation in what looks like a large refinery,. Great amounts of sulphur and coke are produced by the process. Ultimately all the coke will be gassified to make for an energy efficient operation. The sulphur is sold as pure sulphur.

4. Low-Deliverability Gas

New sources of gas are being developed from cretaceous reservoirs in the Deep Basin of Alberta and British Columbia. In addition to normally permeable sandstones and conglomerates are thick sections of 'tight' sandstones with permeabilities in the microdarcy range, porosities under 10 per cent and pre-stimulation productivity of less than 150,000 cubic feet per day. Commercial flow rates can be obtained by massive hydraulic fracturing whereby a deep, vertical fracture is created in the reservoir by injecting sand and frac fluid under high pressure. The sand keeps the fracture open after the frac fluid is recovered and allows the gas to flow to the well bore. While the remaining reserves of conventional gas in western Canada are about 60 trillion cubic feet, estimates of the 'tight' gas in the Deep Basin range up to 400 trillion cubic feet but the producibility of such large reserves or part of them remains to be demonstrated.

5. Frontiers

After one hundred years of exploration in Ontario and western Canada, the remaining frontiers are technological, such as deep drilling in the geologically complex foothills of Alberta and British Columbia, in the ice infested waters of the Arctic and in the offshore areas of Labrador, Newfoundland and Nova Scotia, and British Columbia. Offshore oil exploration began on the Scotian Shelf and Grand Banks in the late 1960's without success except on Sable Island. Land exploration in the Arctic also started in the late 1960's after the discovery of Prudhoe Bay in Alaska, but for offshore northern regions, new technologies and large investments were required, available only in the 1970's.

Large gas reserves have been found in the Arctic Islands and the MacKenzie Delta for a total so far of about 25 trillion cubic feet. Offshore, exploration started in the early 1970's on the Labrador Shelf, and in the late 1970's in the High Arctic and Beaufort Sea. A number of significant gas discoveries have been made in these regions but require confirmation drilling before large reserves can be assured. Important gas with condensate discoveries were made at Bjarni, Gudrid, Snorri and Hopedale from 1973-1978 on the Labrador Shelf. A significant gas discovery was made at Whitefish west of Lougheed Island in 1979. In the Beaufort Sea, gas discoveries were made from artificial islands, and beginning in 1976 Dome Petroleum began its drilling program in the Beaufort Sea using drillships. In 1977, Dome Petroleum established that the Beaufort Sea is an oil province with the discovery of oil and gas at Nektoralik and in 1979, tested large oil flow rates from the Kopanoar

structure. In 1979 also, Chevron established at the Hibernia structure that the offshore of Newfoundland is an oil province. The age of offshore oil in Canada is with us since a few months, but it is only a promise and many years of exploration are required to establish its potential.

Cost of Oil Development

A key element in the options for increased oil production are the capital and operational costs required for development, conveniently referenced to the cost to bring a barrel of oil per day on stream. The costs can be grouped into three categories. Low-cost oil averages about \$2,500 per daily barrel and represents the costs of the bulk of current oil production; medium-cost oil averages about \$7,500 per daily barrel and includes offshore areas like the North Sea and remote but climatically mild on-land areas in Africa and South America; high-cost oil is above \$15,000 per daily barrel and includes synthetic oils and production from climatically severe areas of the Arctic.

The proposed Cold Lake and Alsands oil sand plants are each expected to require investment of \$6 billion for a daily production of 140,000 B/D or over \$40,000 per daily barrel. By comparison, crude oil production from the Beaufort Sea, in water depths of 100 feet, is expected to range from \$7500-30,000 per daily barrel according to the productivity of the fields. There are thus great financial incentives to explore and develop conventional oil in the frontier areas despite the difficulties of the northern marine environment.

There are few difficulties in the drilling of offshore exploration wells in deep water, though the drilling season may be short, but the production of oil from deep water is currently constrained to waters less than about 200 metres. In Labrador, for example, the acreage held by companies with water depths shallower than 200 metres is about 38 per cent while 50 per cent is in depths of 200-500 metres, 7 per cent in waters of 500-1000 metres, and 5 per cent in waters deeper than 1000 metres. There are thus two present technological frontiers: year-round drilling in ice infested waters and production systems in waters deeper than 200 metres.

Rate of Offshore Exploration

The discovery and development of an offshore oil province proceeds through stages of marine seismic surveys, exploratory wells, drilling and production platforms, and lastly gathering flowlines and pipelines from fields to shore. As an example, in the North Sea some 75 wells were drilled in the 1960's prior to the first commercial discovery in 1969. Since then, over 40 major oil and gas fields have been discovered. Current production is over 2 million B/D and will increase as new fields are brought on stream. Exploration is expanding today into new areas such as the Moray Firth, West Shetlands and western approaches.

In Canada, we have seen that offshore exploration is recent and only a few wells have been drilled in northern waters. Much of this exploration has been spurred by frontier drilling incentives, but even so, in 1979 only three wells were drilled in the high Arctic while current drilling in the Beaufort Sea and east coast is expected to complete respectively five and thirteen wells. In passing it may be noted that political, socio-economic and environmental factors have paced exploration, through jurisdictional disputes between Provincial and Federal Governments, land claims, environmental moratoria, restrictions on exports and pipeline delays. A faster rate of exploration is justified by the large number of undrilled offshore prospects and the oil discoveries this drilling season.

Ice Platforms, Subsea Completions and Marine Pipelines

Time will not permit a discussion of the equipment for offshore drilling, production and pipeline systems in which the skill of divers have so important a role. Rather, let us highlight some of the unique operations conducted in the Arctic marine environment.

A system for drilling offshore between the Arctic Islands from ice platforms using a modified land drilling rig has been developed by Panarctic Oils. A camp is located on natural ocean ice at the drill site, holes are bored through the ice and sea water is pumped and flooded on top of the ice to a depth of two inches. The water is allowed to freeze and the flooding is repeated until the ice is built up on top of the ice to a thickness of 12-18 feet. With 40° below zero temperatures and winds of 10-20 miles per hour, the ice can be built up at the rate of 4-5 inches per day. The thickened ice platform can support the drilling equipment and has a rate stress of about 70 pounds per square inch. Thermistor probes, ice profiles and quality, and tide monitoring are undertaken. Horizontal and vertical deflection of the ice platforms are checked during drilling. As long as horizontal ice movements are less than 5 per cent of water depth, drilling can proceed during the five months, January to May season. Ten wells have been drilled from ice platforms by Panarctic Oils, some wells in water depths greater than 1000 feet.

A great advance in offshore completion technology was made by Panarctic Oils in 1978 with the subsea completion of the well F-76 in 200 feet water depth, located in the Drake field of Melville Island. The well was drilled from an ice platform and required a special blowout preventer using a hydraulic control system with an acoustic back-up. The underwater 'wet tree' production system used a diverless remote operated flowline connector. The flowline bundle was pulled to the tree by wire ropes and monitored by underwater television. Repairs to blowout preventer stacks and wellheads will use divers in a 'JIM' or more modern, one-atmosphere diving suit. This method was used on a Hecla field well in 1976 in depths of 900 feet. Dives, one of which lasted 6 hours were monitored by television camera.

The transportation of natural gas from the High Arctic will be by pipeline or LNG tanker. Both are formidable challenges. The Polar Gas projects, managed by Trans Canada Pipelines, has a proposed route from Melville Island, under McClure Strait to Victoria Island, to the mainland near Coppermine where it will join a pipeline from the MacKenzie Delta, and thence to Longlac, Ontario. Key portions of the pipeline are the water crossings, those mentioned and others connecting to other gas fields offshore and on-land on Lougheed, King Christian and Ellef Ringnes Islands. Marine pipelining techniques using laybarges, bottom pull and tunneling will be used. The time frame for production facilities and pipelines is 1985-1995. Similar activities in the Beaufort Sea and off the east coast are expected over the same period.

Role of Divers in Offshore Developments

The role of divers in the coming offshore developments in oil and gas will be an important one. Underwater contractors will require teams of air and mixed-gas divers, many of whom will be specialists in hyperbaric welding, non-destructive testing, subsea completion systems, pipeline engineering, corrosion control and many other fields. Divers need also to become aquanauts, manipulating manned vehicles and working from submersibles and atmospheric pressure vehicles and diving bells.

The job range required by underwater contractors involves costly equipment and systems compatible with other operations aboard drillships, production platforms and pipeline barges. Seabed work including flowlines, risers, trenching, pipeline welding, burial and coating will become progressively more difficult as oil and gas fields are discovered and brought on production in ever increasing water depths. For deep-water platforms, the work will be carried out using atmospheric bells while remotely controlled vehicles ranging from compact movable cameras to complex vehicles with manipulators will be used for underwater inspection, maintenance and even light construction work. Both the variable skills of the divers and the capabilities of underwater robots have their place in offshore oil and gas development. Because we do not yet know at what water depths and under what ice conditions the bulk of our petroleum resources will be found, multiple contingency planning and research is required from all of us, if we are to meet the challenges of petroleum self-sufficiency. Thank you!

CANADA'S ENERGY RESOURCES

by

Mr. S.P. MacKay, P.Eng.

Esso Resources Canada

1. Before I begin, I would like to thank you for the opportunity to talk to you today, about Canada's Energy Resources.

2. My talk will be in two parts; the first part will include a review of energy usage and growth rate in Canada from 1965 to 1979 and a forecast of the demand to 1990. The statistics and forecast will identify historical usage and demand by both prime user and by the different kinds of energy resources.

3. I will then continue with a review of oil and gas exploration and development opportunities in Canada's frontier areas that will provide energy supplies in the future. This review will describe the methods that are being used to drill offshore exploration wells and methods that with few exceptions, are in prototype design and early planning stages, to develop offshore oil and gas reserves in deep water and in areas where Arctic ice is present during many months of the year.

ENERGY DEMAND STATISTICS AND PROJECTIONS

4. Turning now to the historical and projected energy demand for Canada (see Chart), we can see that in 1965, Canadians were using energy at a rate equivalent to 2-1/2 million barrels of oil per day. This consumption was split between residential/commercial, industry, transportation and the use of energy by the energy industry itself.

5. By 1979, the demand had increased to about 4.8 million equivalent barrels and by 1990, we believe the demand will increase to 6.0 million equivalent barrels of oil per day.

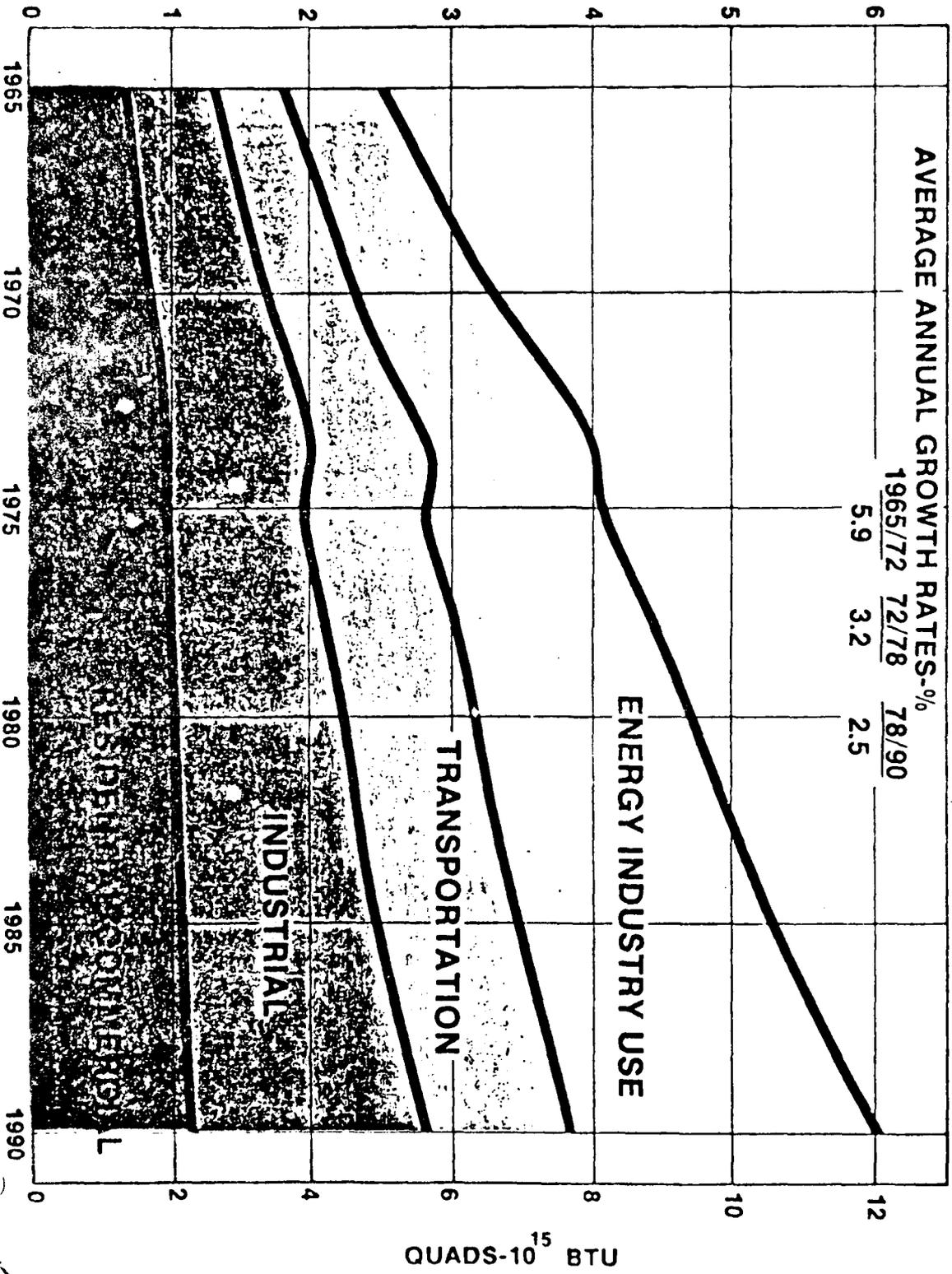
6. It is interesting to note that growth rates have decreased from 5.9% between 1965 and 1972 to 3.2% from 1972 to 1978 and are forecasted to decrease further to 2.5% between 1978 and 1990. We believe this growth rate decrease can be attributed to conservation, more efficient use of energy and cost escalation.

ENERGY DEMAND REDUCTIONS FALL ON OIL AND GAS

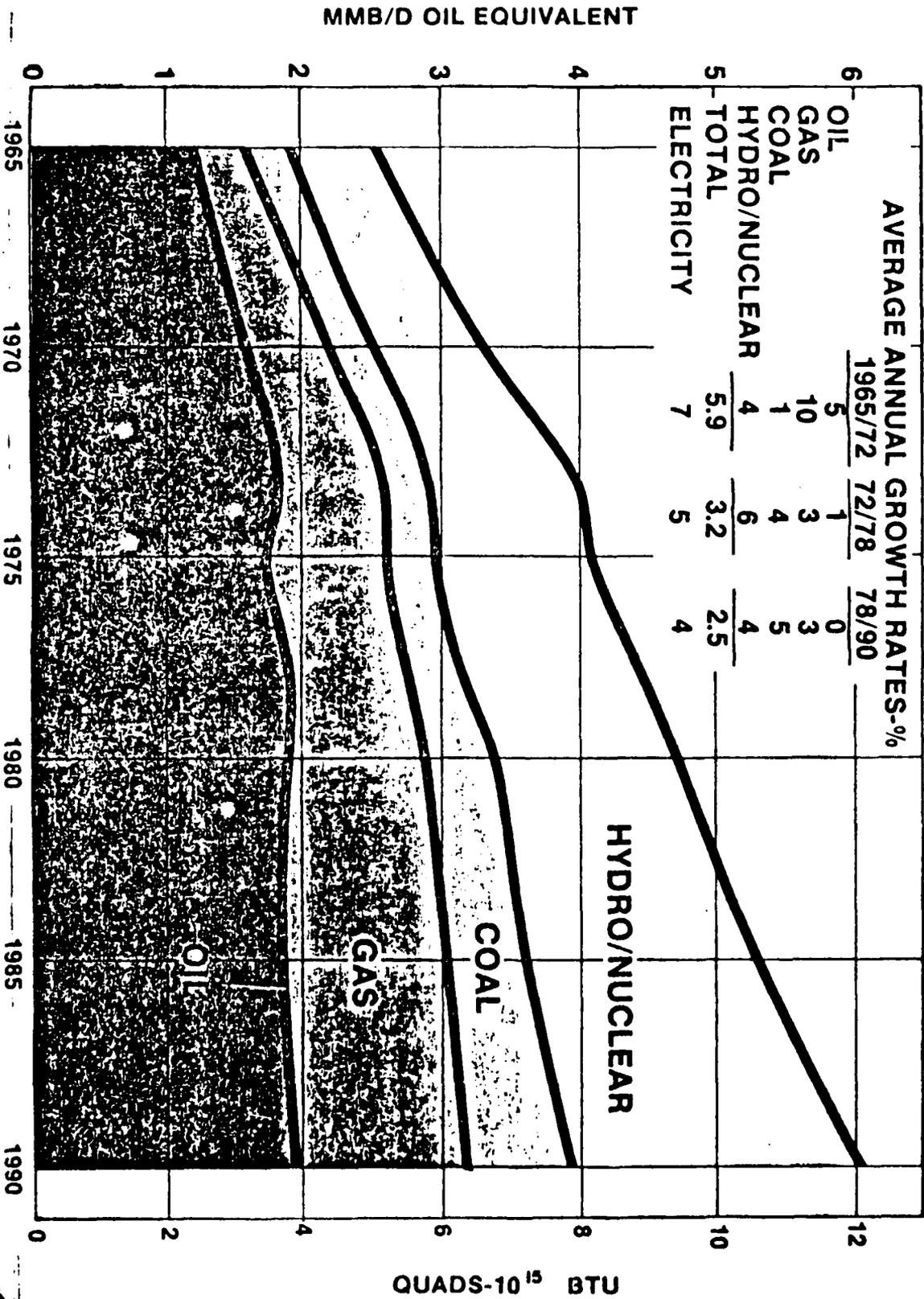
7. In the second chart, we have shown the same demand figures from 1965 to 1990. However, in this chart, the demand is related to the different kinds of energy resources.

ENERGY DEMAND STATISTICS AND PROJECTIONS

MMB/D OIL EQUIVALENT



ENERGY DEMAND REDUCTIONS FALL ON OIL AND GAS



8. Hydro/nuclear power will make up about two-thirds of the increased energy demand of 1.2 million equivalent barrels of oil per day between now and 1990. Coal and gas will make up the other third of the increased demand. It is interesting to note that we expect the growth rate for coal will be higher than that for the other energy resources. Oil consumption is not expected to show any growth and will remain stable at about 2 million barrels per day.

9. In the forecast period to 1990, we expect conventional oil production will decline from about 1.5 million B.O.P.D. to about 1.0 million B.O.P.D. This reduction in conventional oil production will be made up by Athabasca tar sands oil and by the in-situ production of substantial heavy oil reserves at Cold Lake, which is located near Lloydminster, on the Alberta/Saskatchewan border.

10. We do not expect frontier gas or oil reserves will be on stream before 1990. Nevertheless, we expect there will be substantial activity in Canada's frontier offshore areas that may be of more interest to the diving community than conventional on-shore or heavy oil development. Accordingly, I will proceed to identify these frontier areas geographically, and provide some background on the status of discovered reserves or discovery well rates where figures have been published. I will then review the state-of-the-art technology for exploration drilling and present some production equipment design concepts that are already in the prototype design stage, or could be developed for the production of offshore oil and gas reserves in frontier areas.

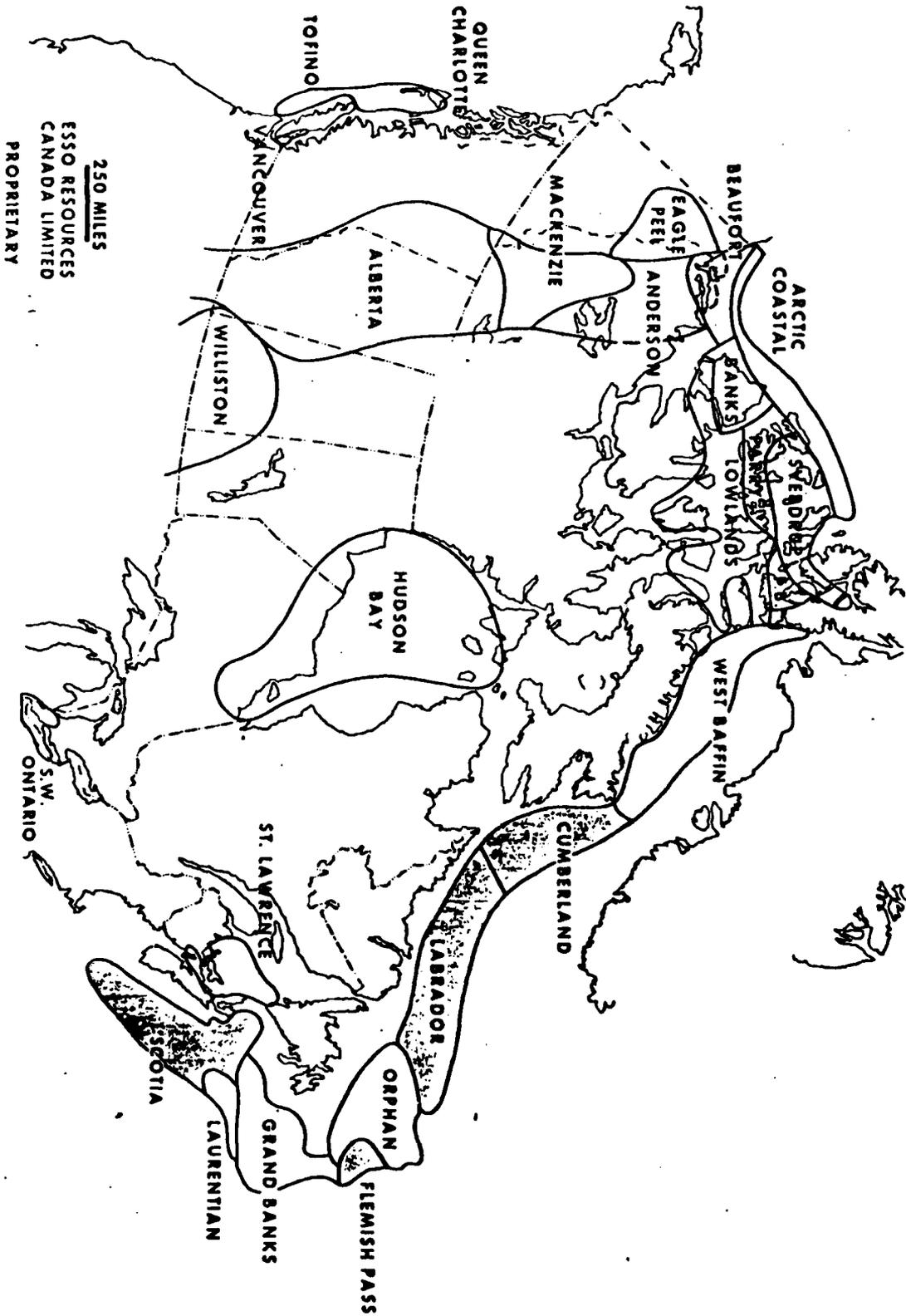
FRONTIER DEVELOPMENT OPPORTUNITIES

11. Frontier exploration and development opportunities range across the Arctic and down the east coast from Baffin Island to Nova Scotia. The prospective sedimentary basins include the Beaufort/MacKenzie Delta area, the Arctic islands or Sverdrup Basin, West Baffin, Cumberland/Davis Strait, Labrador Shelf, Orphan, Flemish Pass, Grand Banks, Laurentian and the Scotian Shelf. The active exploration drilling basins are shown in red.

12. Gas reserves of 5.5 tcf in the Beaufort, 16.5 tcf in the Sverdrup and about 2.0 tcf on the Scotian Shelf have been reported. There have also been some modest oil discoveries in the Beaufort during the past 10 years. Dome recently estimated a substantial flow rate capability of 12 thousand B.O.P.D. on their Beaufort Kopanoar discovery well. Panarctic reported a non-commercial oil discovery at Bent Horn in the Sverdrup Basin in 1974. Chevron reported a flow rate of 800 B.O.P.D. from their Hibernia location on the north-east, Grand Banks this summer.

13. In summary, substantial gas reserves have already been found in frontier areas and as a result of reported oil discoveries this year, the prospect for substantial frontier oil reserves has increased dramatically.

FRONTIER DEVELOPMENT OPPORTUNITIES



14. I would now like to take a few minutes to talk about exploration drilling and conceptual, oil and gas development technology for the active frontier offshore basins.

EXPLORATION SITES

15. Beaufort offshore oil and gas exploration permit acreage ranges from the shoreline to about 400 feet of water. Esso holds most of the Beaufort permit acreage out from the shoreline to 60 feet of water. During the past 10 years we have dredged 15 artificial islands to drill exploration wells. These islands have been constructed in water depths ranging from 5 feet to 60 feet of water where our Issungnak Island is currently under construction. Esso has had limited exploration success offshore, but gas reserves of 3 tcf have been proven up at Taglu on Richards Island. Esso expects to continue to drill in the Beaufort at a pace of about one or two wells per year including both onshore and offshore wells. A picture of Immerk, our first island, is shown in the next illustration.

16. Immerk was completed in 10 feet of water in 1973 for a cost of about \$5 million. As you would expect, there have been many technological advancements associated with dredging and Arctic logistics that have been essential to increasing our construction capability from 10 to 60 feet of water over the past 10 years.

17. In the deeper part of the Beaufort, beyond 60 feet of water, Dome have been drilling exploration wells with ice reinforced drillships since 1975. Drillships have been used around the world for drilling exploration wells for many years.

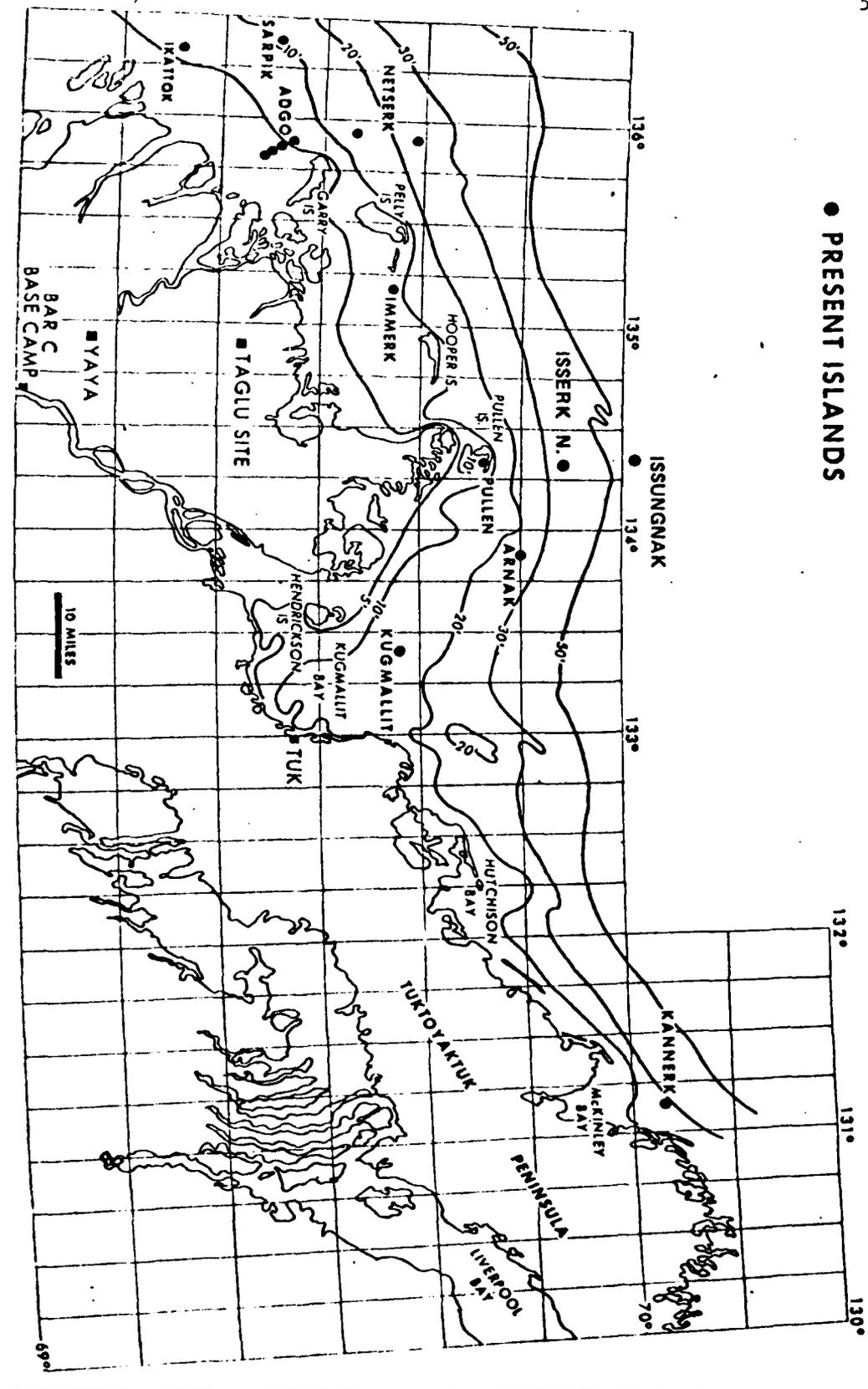
DYNAMIC POSITIONING

18. The schematic diagram shows the principal components which will permit drilling from a floating vessel. The ship is maintained on location by either mooring cables or as in the illustration, by a series of thrusters that position the ship dynamically over the wellhead which is located on the sea floor. The Dome drillships use conventional mooring cables and anchors in the relatively shallow water of the Beaufort. Most rigs in deeper water on the east coast are dynamically positioned. The second most important floating drilling system component is the marine riser which consists of a pipe about 18 inches in diameter through which the drilling tools are lowered to drill the well. Drilling fluids and formation drill cuttings are also circulated back to the drillship through this pipe. The well control equipment is located on the sea floor and is remotely operated.

19. The drillship shown here is the CanMar Explorer I. Dome are now operating four drillships in the beaufort and have drilled nine exploration wells over the past four years. Dome have reported that three

EXPLORATION SITES

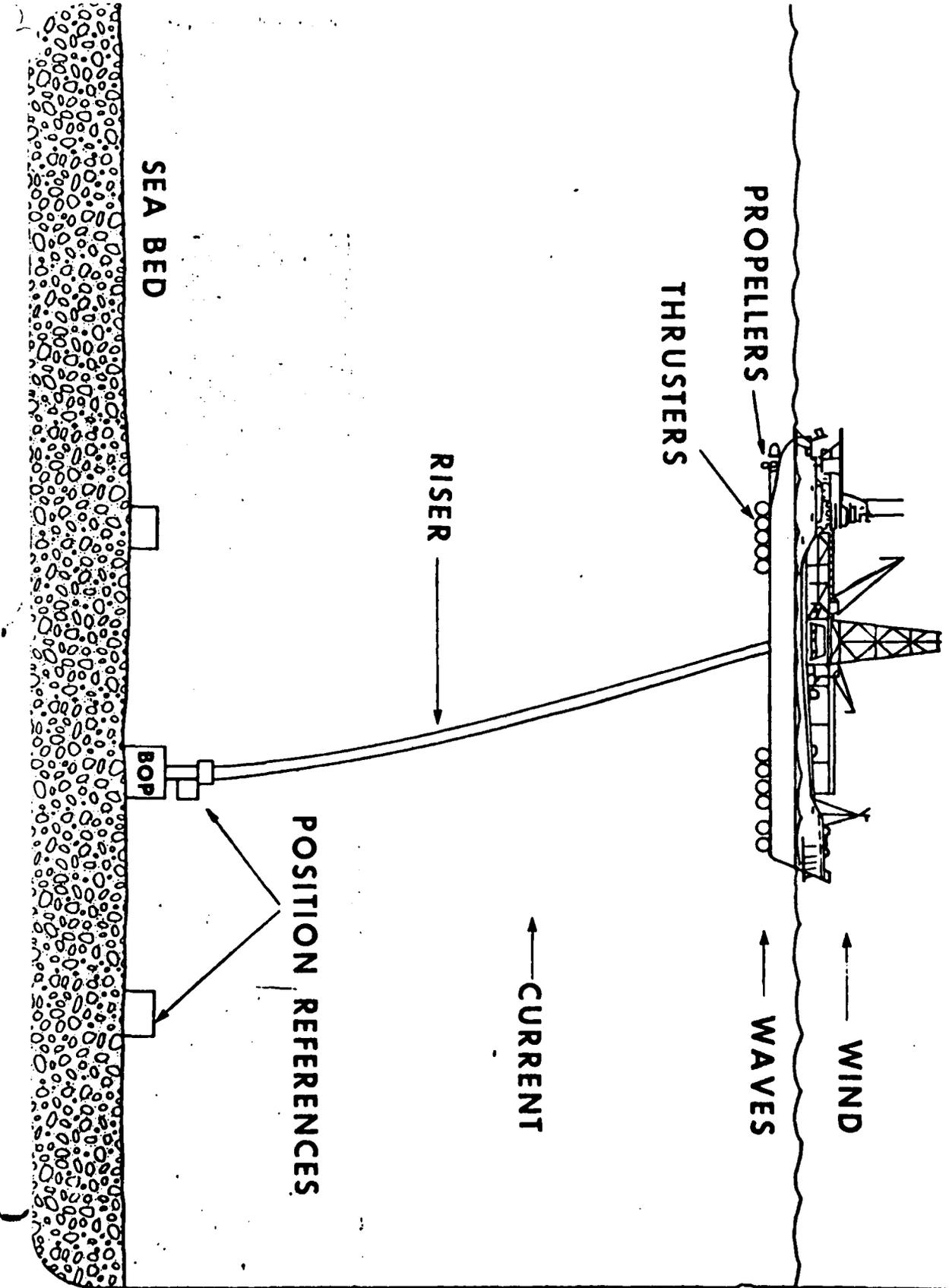
● PRESENT ISLANDS

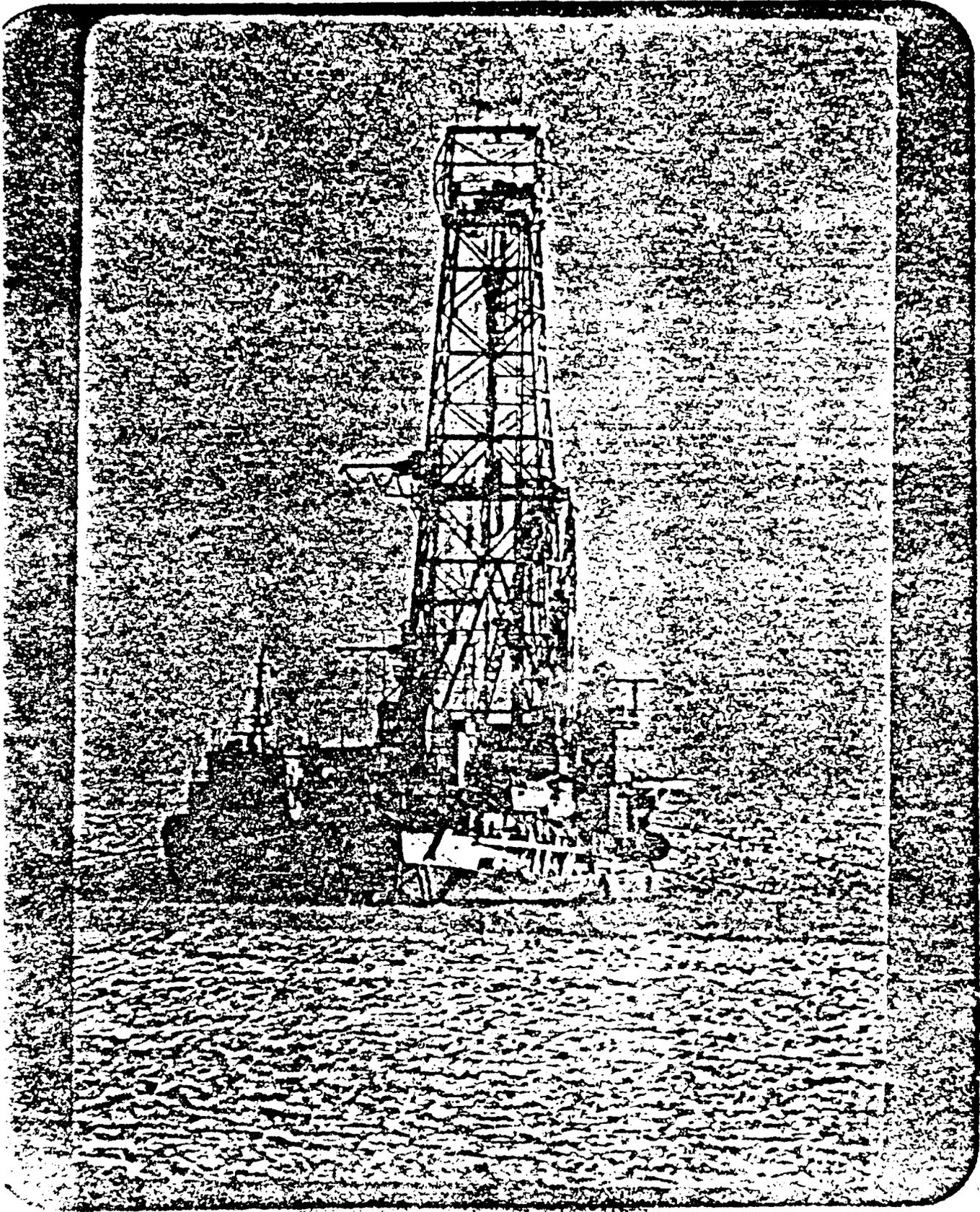




THIS PAGE IS FROM THE ORIGINAL SOURCE
FRONT VIEW OF THE HUMAN TORSO

DYNAMIC POSITIONING





wells tested gas and two tested oil out of the nine drilled.

20. As discoveries are made, Beaufort operators will need to develop production and transportation systems to drill and produce development wells and move reserves to market. These systems will have to be designed to resist offshore environmental loads. Accordingly, environmental studies have been done by Esso and others to determine ice, wave and wind design load criteria. Using these design criteria, a number of production platform concepts have been developed.

21. For example, we believe our caisson retained island can be designed to work in at least 100 feet of water in the Beaufort. The structure consists of a series of eight caissons tied together internally with cables. The structure is floated to site and ballasted down onto a sand-fill berm, constructed by a dredge in the previous open water season. The centre of the caisson is then filled with sand to provide a surface for drilling and production operations.

22. One of the key features of the caisson is in the outer wall which is constructed to intersect the ice at an angle of 45°. In this way, as the ice moves against the caisson under wind loads, the ice fails in flexure at a much lower load than would occur in a vertical wall caisson configuration.

23. The steel monocone structure, which is another Beaufort production platform concept, also fails the ice in flexure and has potential for application out to 200 feet of water.

24. In summary, industry has been innovative in the development of capability to drill exploration wells in the Beaufort Sea. Conceptual production platform alternatives have also been developed to ensure that reserves can be produced and transported to market in a reasonable time frame as they are discovered. We believe that a reasonable time frame in frontier areas is about 10 years.

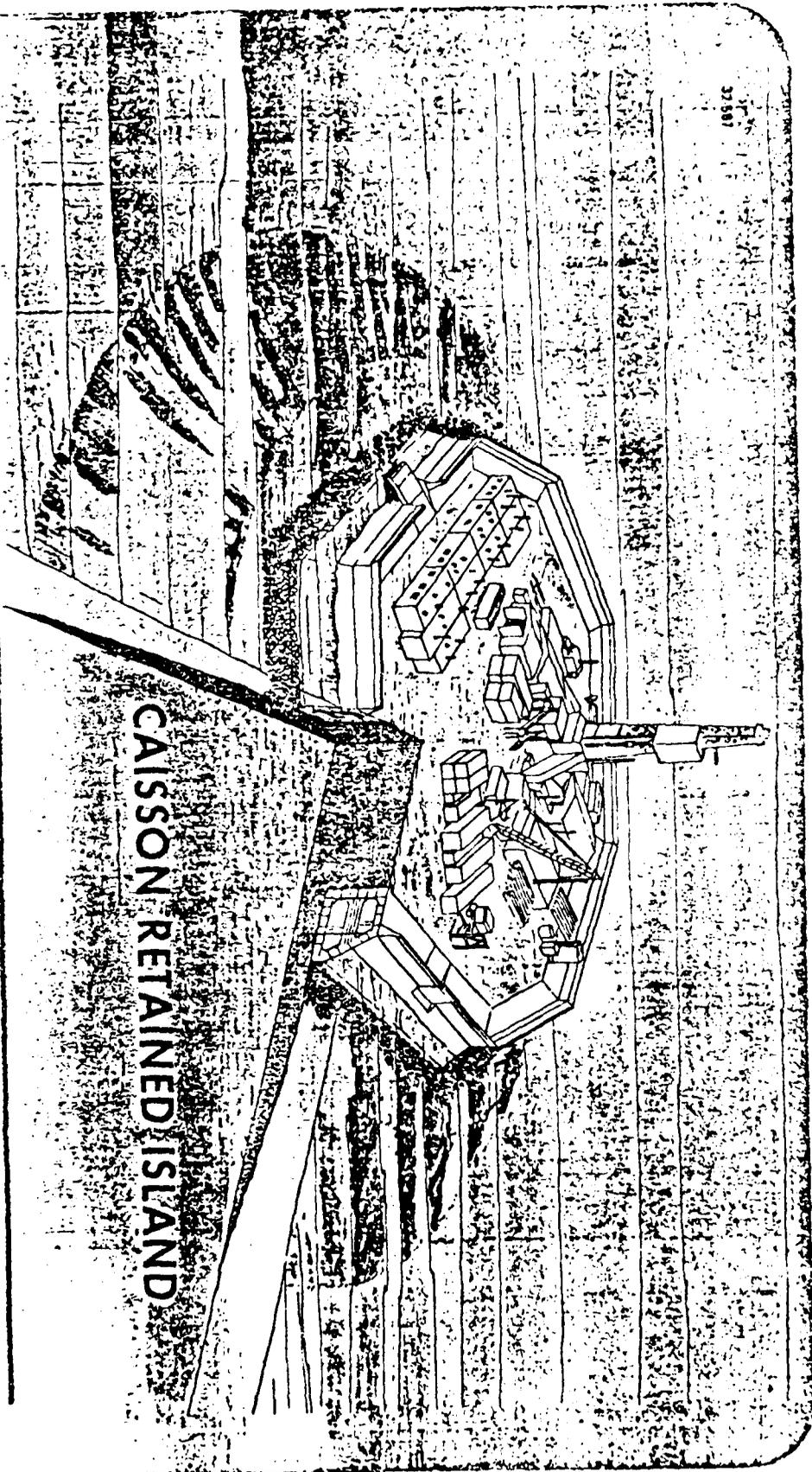
25. I would like to turn now to the Arctic Islands, Sverdrup Basin where a number of gas discoveries have been reported over the past few years. As I mentioned earlier, reserves here are now estimated at 16.5 tcf.

ARCTIC ISLANDS GAS RESERVES

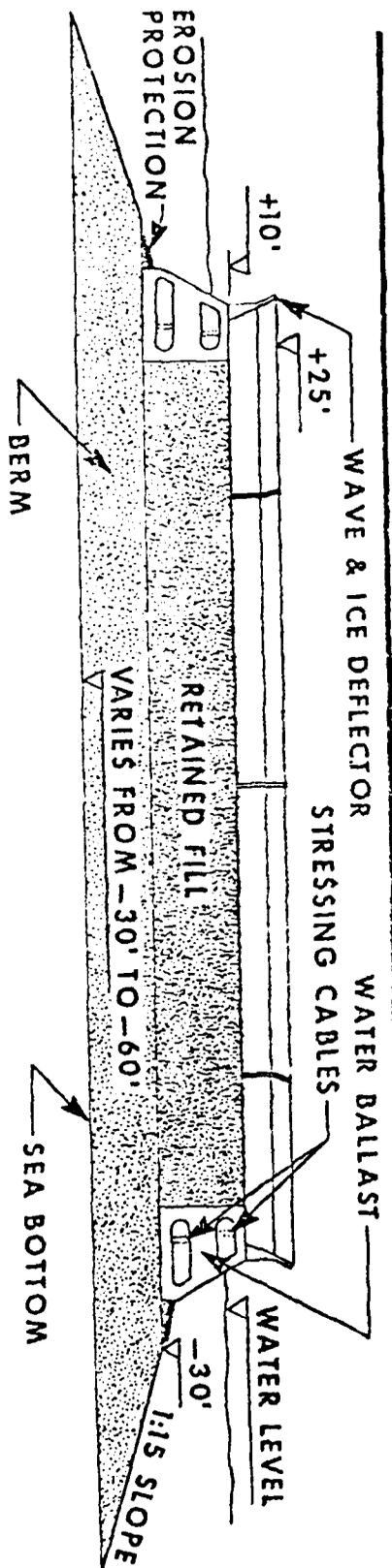
26. Panarctic is the most active operator in the area and have an interest in nearly all of the discoveries. In addition to the discoveries shown here, a new discovery was announced earlier this year at Whitefish, off the north-west corner of Lougheed Island.

27. Because the ice in the offshore Sverdrup Basin moves very little during the winter, Panarctic was able to develop some new technology related to thickening the natural ice sheet to provide a platform for a

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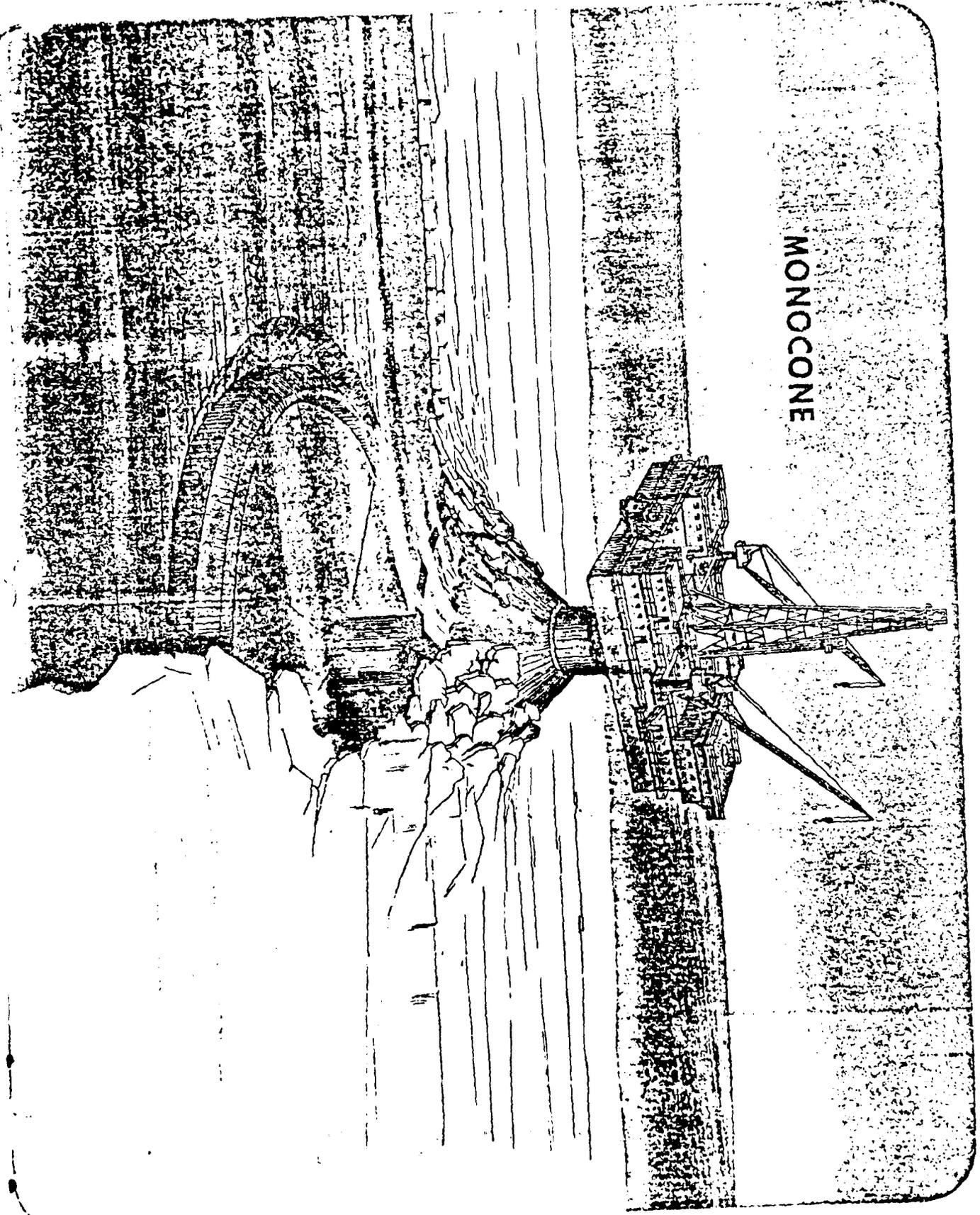


CAISSON RETAINED ISLAND

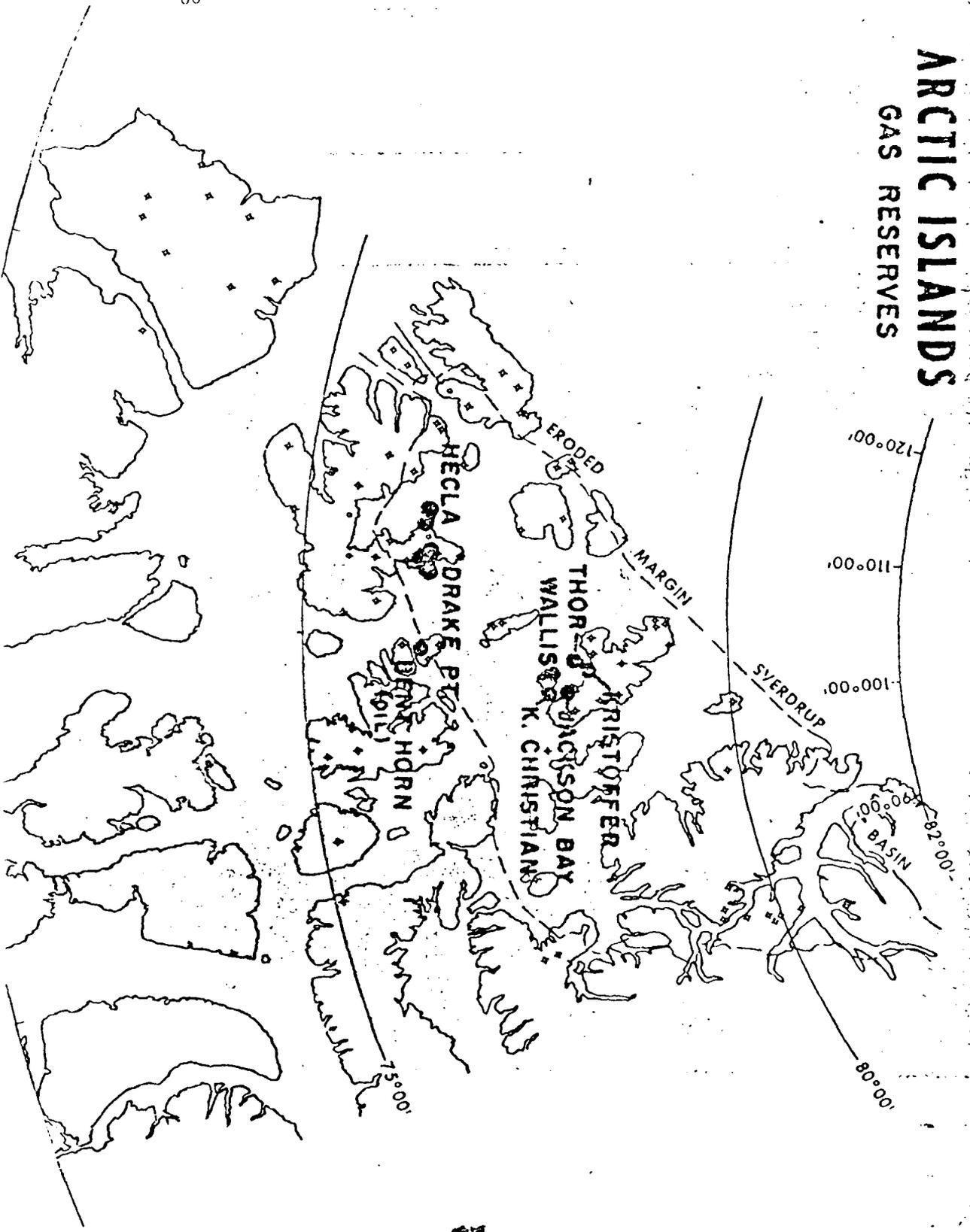


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MONOCONE



ARCTIC ISLANDS GAS RESERVES



U.S. GEOLOGICAL SURVEY
BULLETIN 1000
1952

drilling rig to drill offshore exploration wells.

28. The schematic diagram shows the drilling rigs sitting on the thickened ice sheet with a tubular marine riser extending to the sea floor. Unlike drilling ships, the well control equipment is located at the ice surface under the rig.

29. Panarctic have now drilled thirteen wells from floating ice islands. A total of 147 wells have been drilled in the Arctic Islands.

30. We expect the drilling activity in the Sverdrup will continue at about five wells per year in the near term.

31. Panarctic have also been working on development concepts for oil and gas production and have built, installed and tested a prototype gas production system at Drake Point.

32. This system consists of a method for pulling a flowline bundle from the shoreline out to the subsea wellhead where a remote connection is then made to the wellhead. The flowline bundle consists of a number of lines for flowing gas to shore, for hydraulic power fluid to perform mechanical wellhead functions and for the injection of special purpose chemicals. A plough and sled assembly are provided on the lead end of the flowline bundle to dig a trench for the bundle as required.

33. In summary, sufficient work has been done to provide assurance that technology can be developed to produce oil and gas from the Beaufort and the Sverdrup Basin. The next logical question is how will the reserves be moved to southern markets.

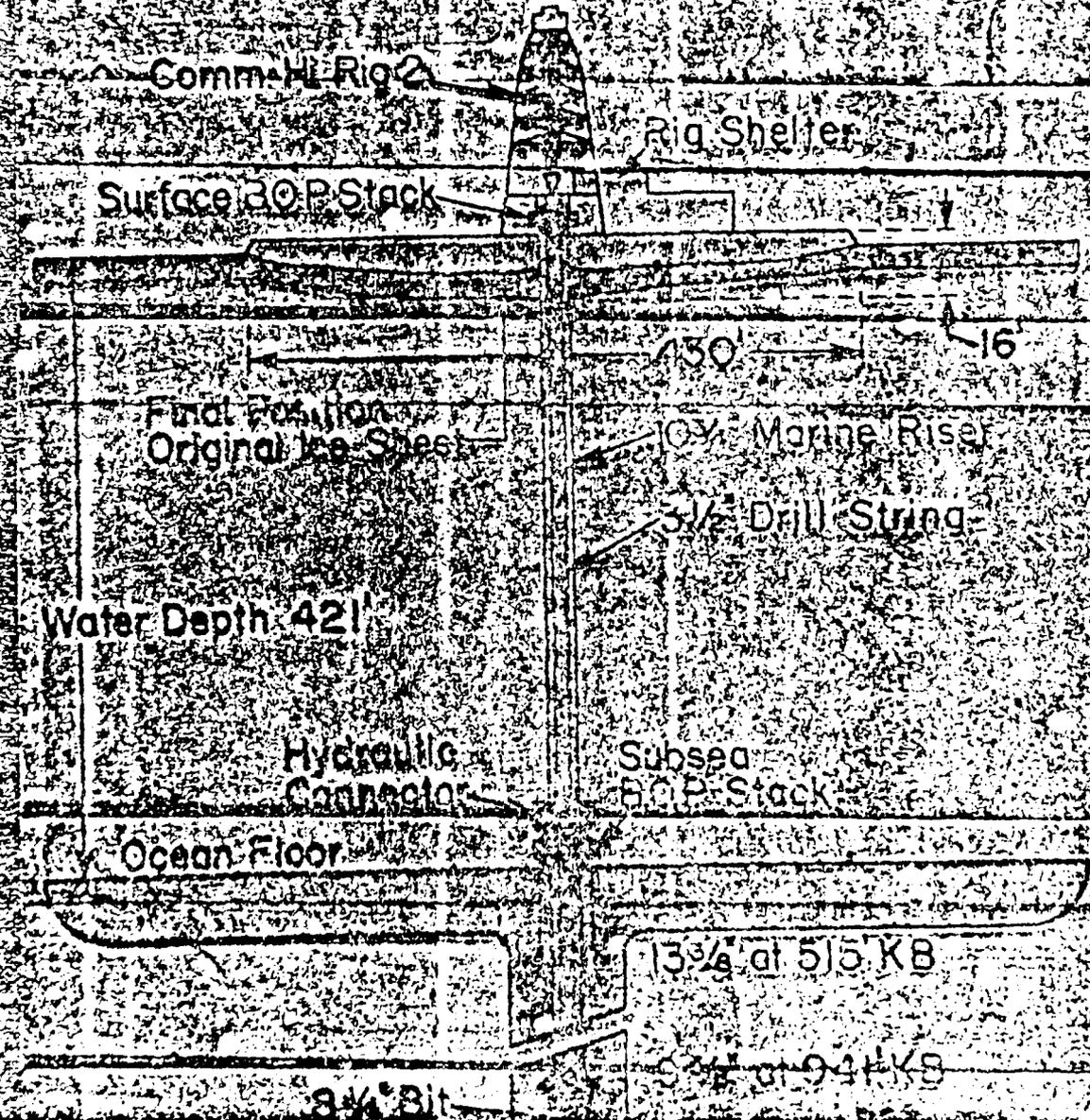
TRANSPORTATION ALTERNATIVES

34. Four transportation alternatives have been studied in varying detail. These include:

- a. The Dempster Lateral to the foothills line to deliver Beaufort gas;
- b. The Polar Gas Wye Line to deliver both Beaufort and Arctic Islands gas;
- c. The Polar Gas West Hudson's Bay line to deliver Arctic Islands gas only; and
- d. A Petro Canada Lng proposal for Arctic Islands gas.

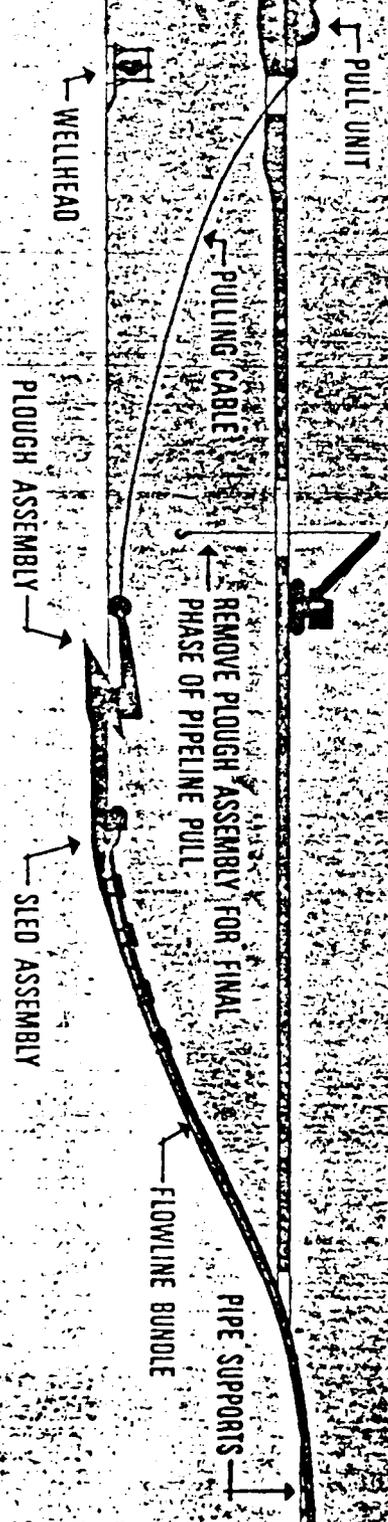
35. In addition to the above gas transportation alternatives, we understand Dome are studying the use of ice reinforced tankers to transport Beaufort oil reserves to market.

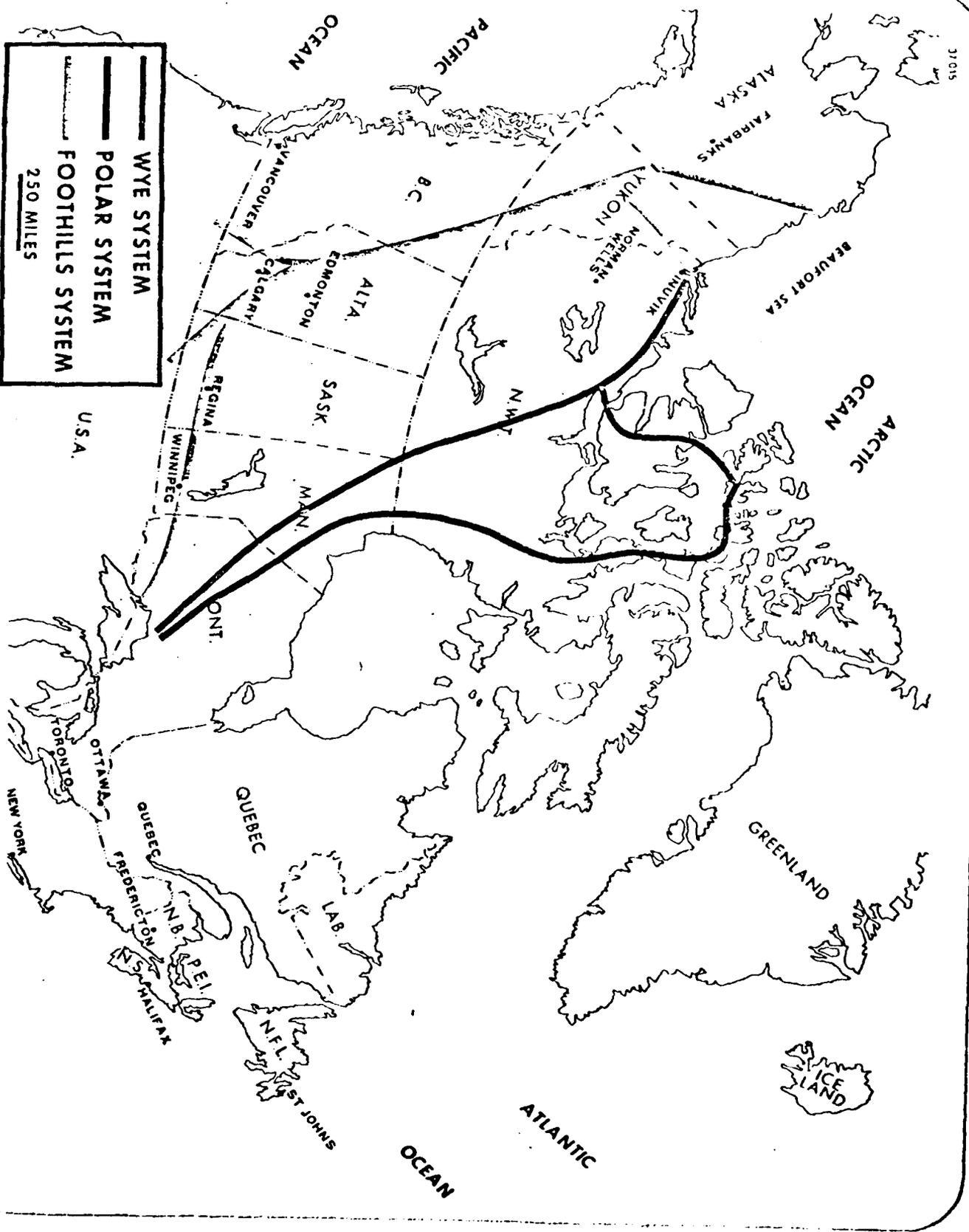
ICE PLATFORM DRILLING AT HECLA 1974



GEORGE

DRAKE POINT EXPERIMENTAL COMPLETION FLOWLINE BUNDLE INSTALLATION





	WYE SYSTEM
	POLAR SYSTEM
	FOOTHILLS SYSTEM
	
250 MILES	

36. Transportation route selection and construction will depend on a number of considerations including a gas export decision, market opportunity, pipeline cost estimates and associated transportation tariffs, environmental impact and the assurance of threshold reserves.

37. I would now like to take a few minutes to look at our east coast exploration and development picture.

38. Some of the east coast operators are identified on this chart. A number of other joint interest operators including Petrocan, with wide-spread interests, are not shown on the chart.

39. Water depths on the permits range from shoreline on the Scotian shelf to 3000 metres on the Orphan Block. Some of the permit acreage extends more than 250 miles from shore. Sea ice, with ridges up to 15 feet in thickness, forms along the Labrador coast extending up to Lancaster Sound for several months each year. Large numbers of icebergs of varying sizes also move down the Baffin/Labrador coast each year.

40. Despite the environmental challenges, this area was one of the most active offshore exploration areas in the world last year. Nine drillships were used to drill eleven wells. Esso will complete two wells in the area by year end using the SEDCO 709 dynamically-positioned semi-submersible drilling rig which is very stable even in heavy sea conditions.

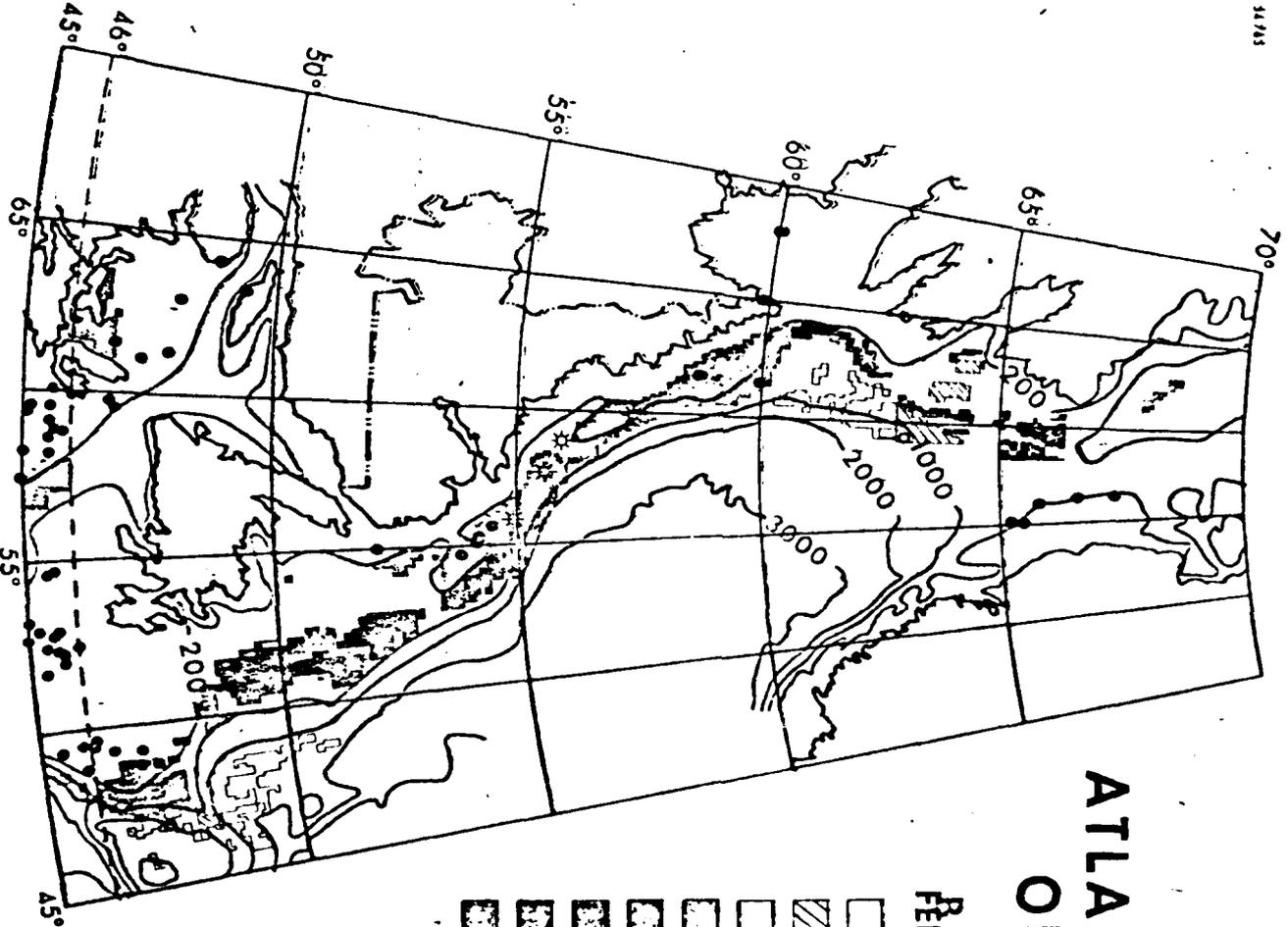
41. The SEDCO rig uses eight thrusters with a total of 24,000 horsepower to maintain position above the wellhead location on the sea floor.

42. The box-like, cylindrical column configuration of the hull is more transparent to wave loads than the hull of a conventional ship. For this reason, the seaway response motion of the vessel is reduced so that it can work more efficiently in heavy seas.

43. To summarize the oil and gas exploration picture on the east coast, over 130 wells have been drilled between the Scotian shelf and the Davis Strait. Both gas and oil discoveries have been reported and some preliminary development plans and feasibility studies have been initiated.

44. Relative to development planning, sea ice, icebergs, deep water and distance from shore can present some unique challenges related to both production platform design and pipelines, particularly in the area east and north of Newfoundland. Subsea production system concepts which do not require a fixed platform or a pipeline may resolve some of the environmental challenges.

31 213

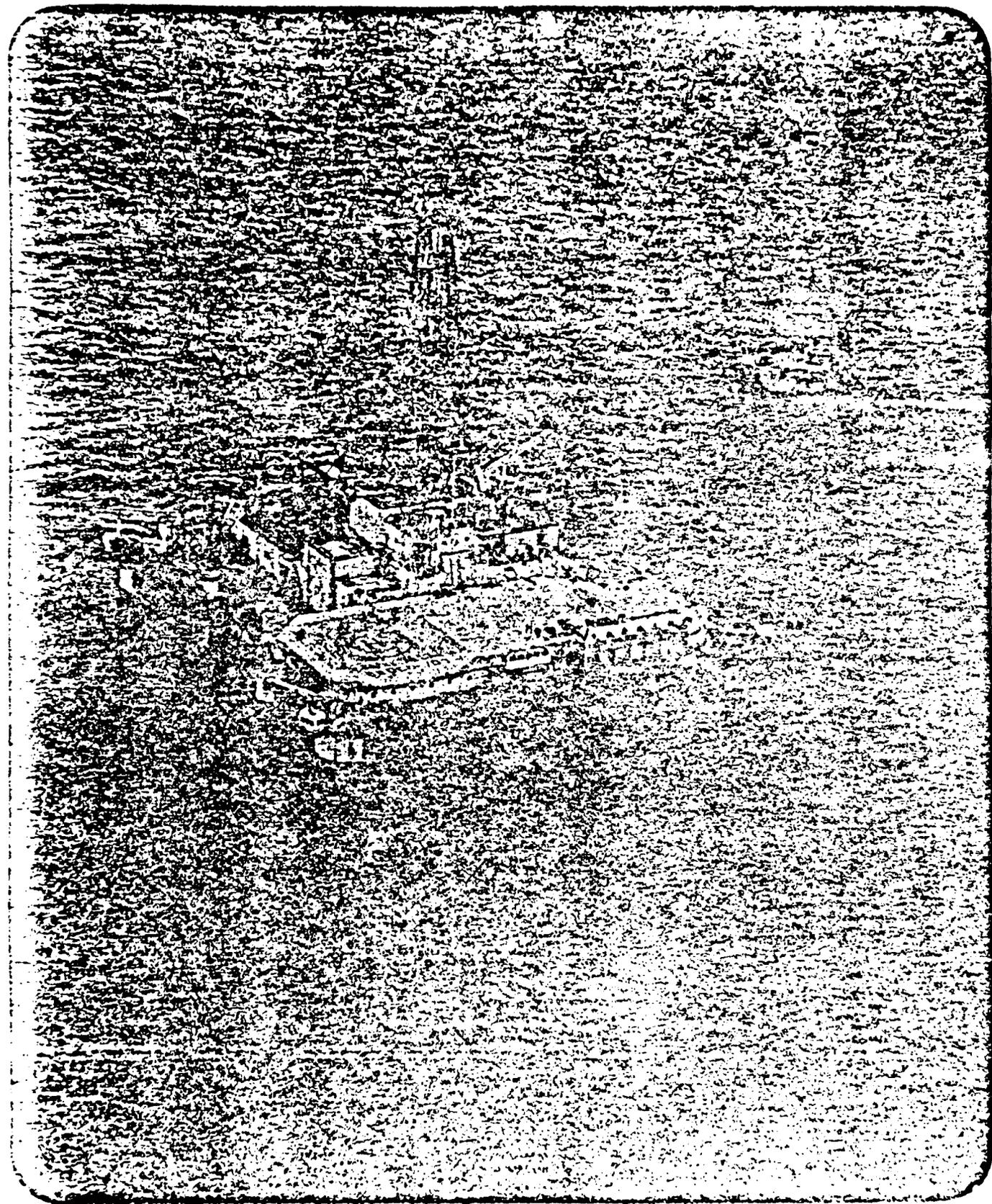


ATLANTIC COAST OFFSHORE

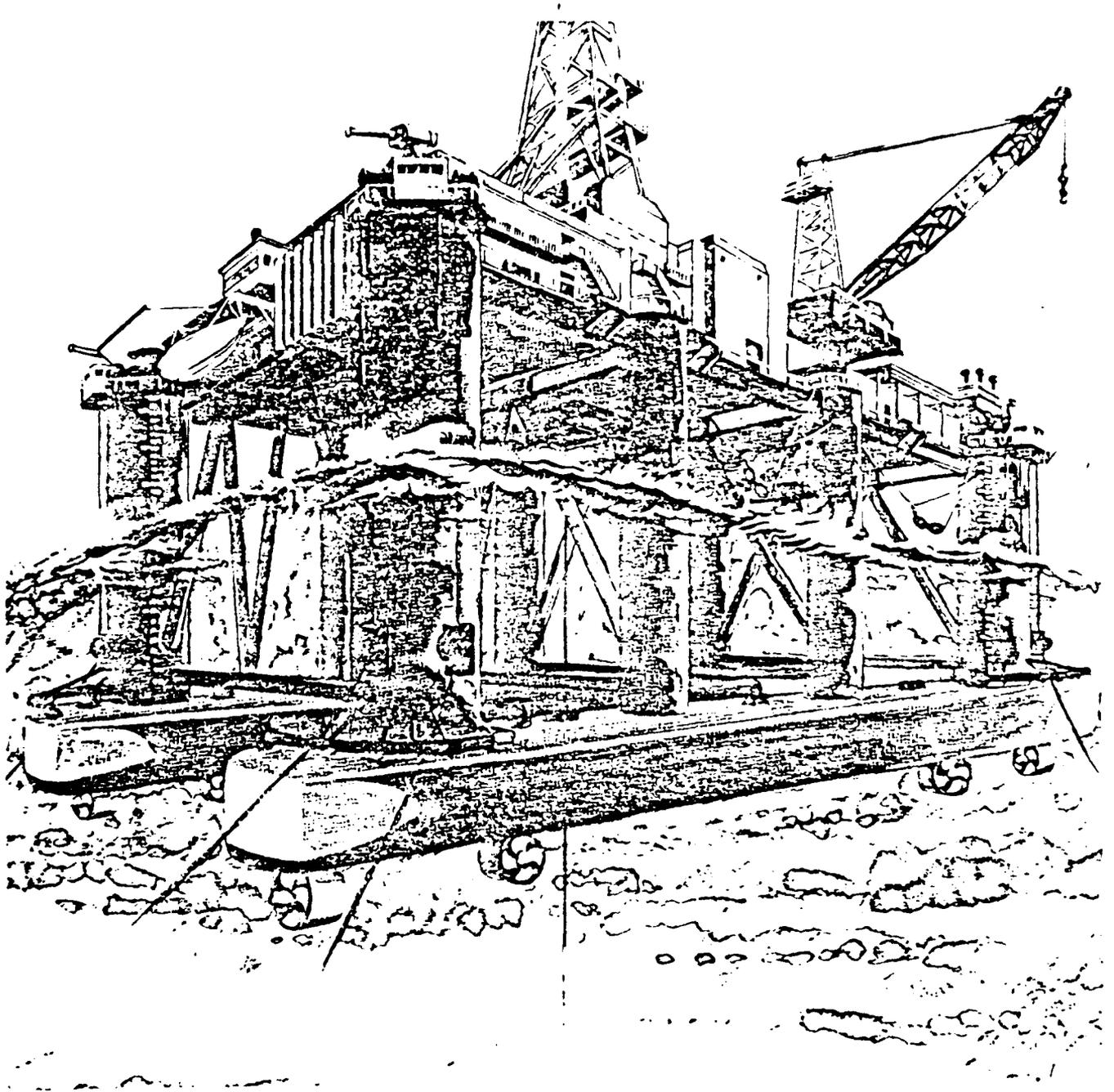
FEDERAL PERMITS

-  ESSO
-  ESSO INT.
-  SHELL
-  EASTCAN
-  HBOG
-  AQUITAINE
-  BPOG
-  MOBIL

200 MI
300 KM



SEDCO 709



SUBSEA PRODUCTION SYSTEM

45. In one subsea production concept, several wells are drilled through a template on the ocean floor. The combined production from these wells is then flowed through a production riser to a storage tanker where the oil production is in turn offloaded to a shuttle tanker and moved to market.

46. A prototype ocean floor drilling template of this type has been designed, constructed and tested in the Gulf of Mexico. The picture shows this template being towed out to location.

47. Other east coast development feasibility studies have included the construction of deep water rock island platforms and the development of deep pipeline trenching capability to overcome iceberg-associated problems.

48. The Scotian Shelf, Sable Island area where Mobil have reported gas reserves, is the only frontier area where it appears that conventional offshore production platform and offshore pipeline technology is on the shelf.

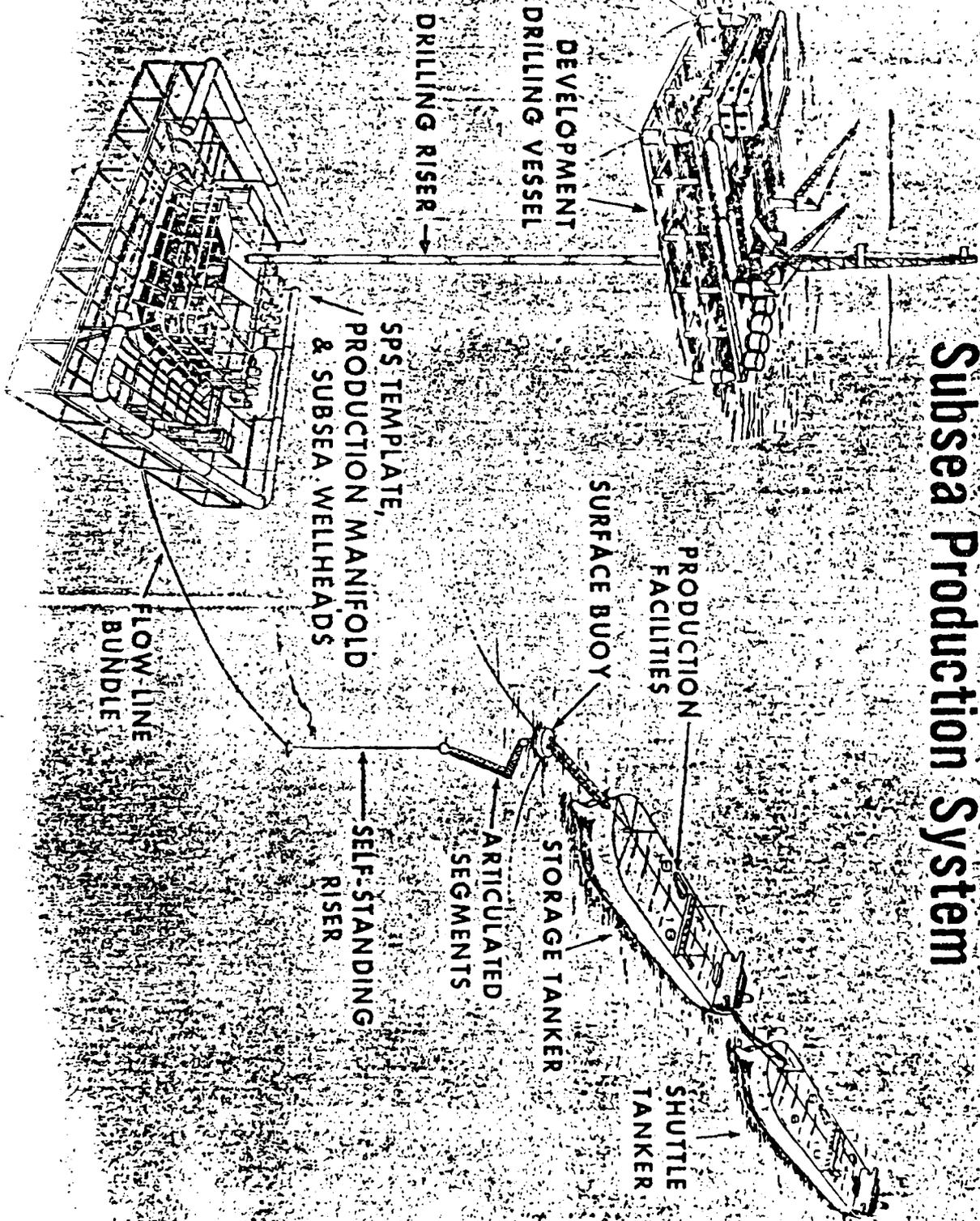
CONCLUSION

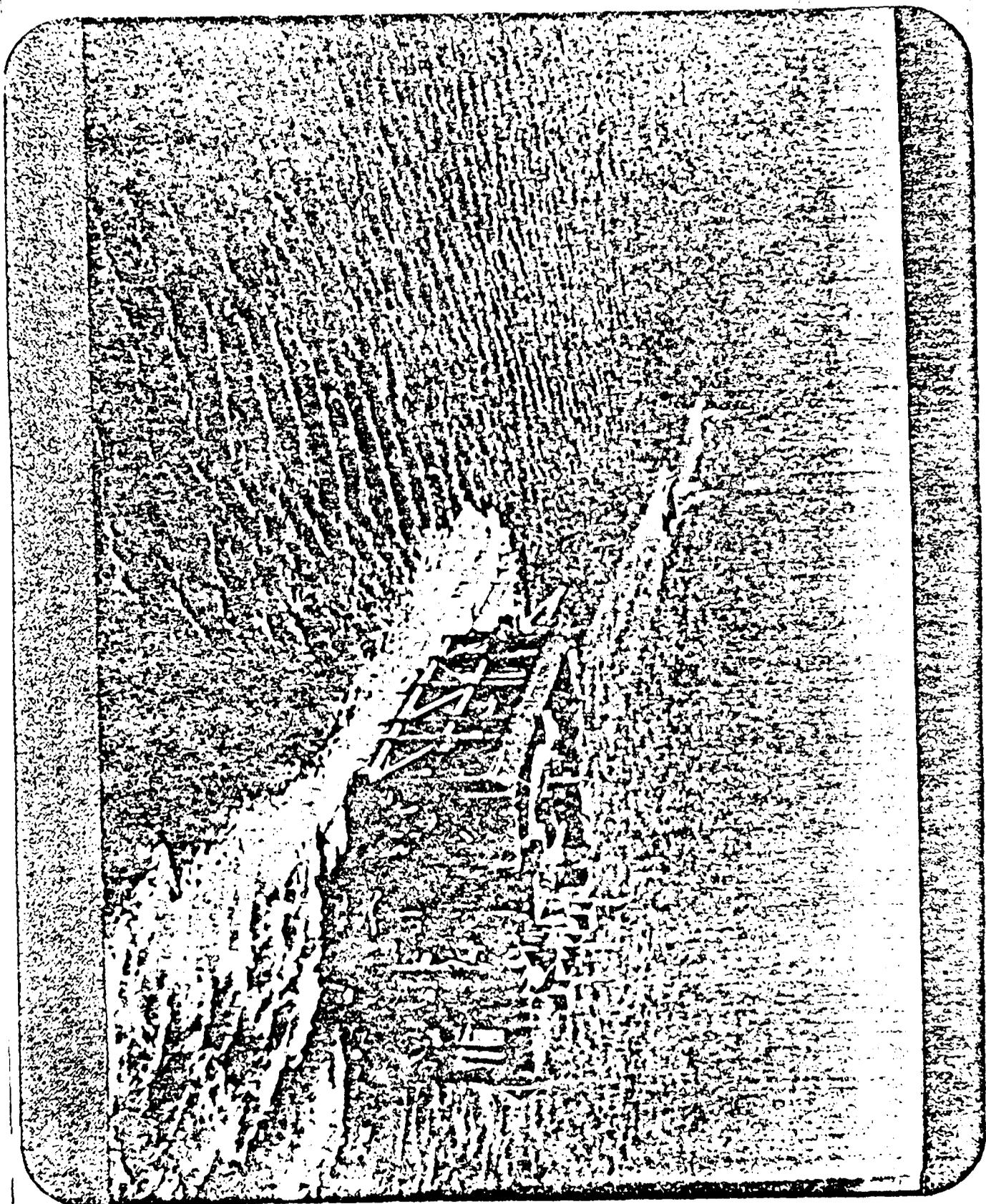
49. In conclusion, to try to relate back to the diving community, I have not identified any specific potential need for diving expertise in projected frontier oil and gas exploration and development activities. Many of the development concepts under study are diverless, wet systems. However, some of these will use unmanned submersibles for maintenance and some conceptual work has started on these systems in the U.S. and Europe where subsea production design work has been underway for about 10 years.

50. The Lockheed subsea production system has been designed as a one atmosphere system and may have some application in Canada.

51. In general, the trend in the oil and gas industry is to diverless or unmanned diving systems. For those in the diving community who are interested in commercial opportunities, I believe the challenge rests with the community to acquire sufficient knowledge of subsea production technology to identify potential opportunities for diving services and to work with the subsea production system design experts to develop equipment and capability to provide a useful, efficient service.

Subsea Production System





TECHNICAL ASPECTS INVOLVED IN A
YEAR ROUND STUDY OF KELP GROWTH
AND PHYSIOLOGY IN THE CANADIAN
HIGH ARCTIC

By

S.F. Watts and A.R.O. Chapman, Ph.D.
Dalhousie University

INTRODUCTION

Dalhousie University Marine Biologists have been conducting year round research utilizing S.C.U.B.A. diving equipment for over a decade.

The university is located in Halifax, Nova Scotia, with water frontage on the North West Arm and within 2000 miles of coastline. Its geographical location, combined with the excellent research facilities available such as Bedford Institute of Oceanography, Fisheries Research Board, National Research Council, Nova Scotia Research Foundation and The Defence Research Establishment Atlantic, probably make it one of the best locations in Canada for marine studies.

In 1973-76 Dalhousie University biologists conducted an extensive marine study. It was during this period that the university added a professional diver to its staff to co-ordinate its diving activities.

INITIAL PLAN

In early spring of 1978, Dr. Tony Chapman, one of the university's leading pshchologists and a seasoned S.C.U.B.A. diver received a \$25,000 grant from the National Research Council to conduct a year round study of kelp productivity and physiology in the Canadian High Arctic. The question that this study was meant to answer was: how much do kelps contribute to marine food chains?

One of our first problems was: could we work year round (winter included) with a small team and with a small budget?

To my knowledge, to this point there had never been any year round diving projects conducted in the Canadian Arctic so there was not much literature available on polar diving techniques. There have been many diving projects conducted in the Arctic for brief periods, most of them during the summer months and most with military or military size diving teams.

RESOURCES

Personnel

Chapman, Gagne, Lindley, Watts, Wharton.

There were two to three personnel sent per trip by Nordair/First Air. It required 13 hours to travel from Halifax to Igloolik under the best circumstances, with the longest trip requiring 48 hours in February, 1979. There were eight trips made from May, 1978 until August of 1979.

Equipment

The equipment was sent air express from Halifax at a cost of \$1.00 per pound; cost \$1,000.00. It included: four (4) diving cylinders, 1.8 C.F.M. Mako gasoline driven compressor, two (2) complete sets of diving equipment, and the required scientific equipment. This equipment was shipped home by sea lift at a cost of 10% of air freight.

SITE SELECTION

Igloolik Island is a small island in Foxe Basin, Lat. 69° 20'N, lying off the north-eastern extremity of Melville Peninsula at the entrance to Fury and Hecla Strait. The island has roughly the shape of a horseshoe, forming a well protected harbour with deep water and a tidal range of about two metres.

It was selected from two possible year round laboratories. The laboratories are intended to assist government, university, industrial scientists and any other research workers with a valid interest in northern science. They provide facilities to allow a range of laboratory investigations to be conducted in the north and are open year round.

Frobisher Bay was considered unsuitable because of ice conditions caused by a 40-foot tidal range and also because it was sub-arctic.

Igloolik was ideal. The laboratory is located in the village and is approximately 400 yards away from the beach (Turton Bay). The mouth of the bay faces south and the prevailing winds are from the north. The bay is relatively free of floating icebergs.

The Department of Indian and Northern Affairs provides free facilities for scientific personnel, including accommodations, laboratory space and laboratory equipment. Most important, they supply other support equipment such as snowmobiles, bombardiers, trucks, boats and outboard motors. They also have a large workshop, adequately supplied, which is made available for visitors use.

Having selected Igloolik - was there any kelp? Our initial dive revealed that there was an abundant supply of the plants.

OPEN WATER DIVING

The research project was set up during the open water period of 1978. The open water period generally extends from the end of July to early October but it may vary by a few weeks. In 1978 the ice did not move out until August 15.

The kelps were found ranging in depth between 5 metres and 22 metres. There was no intertidal or shallow water seaweed. This is probably due to the ice scour which removes them. The major problem caused by ice scouring is "rock flour", a soft limestone substrate. This is ground rock powder caused by shifting ice. This forms a sediment of up to 30 centimeters thick on the bottom. It creates a major visibility problem when working on the bottom. Also, the summer visibility is restricted by the plankton bloom in August. The site was located approximately two miles from the village and in a water depth of eight metres.

During this summer operation, the following tasks were completed:

- (1) Plants were collected from 30 quadrats (each quadrat is 1/4 square metres). These plants were weighed for biomass. The biomass was found to be 1 kilogram fresh weight per m^2 . This is considered to be rather low and is probably a result of the lack of hard substrate for kelp attachment;
- (2) A recording light meter and a temperature recorder were installed on the bottom;
- (3) 30 plants were tagged and measured;
- (4) Water samples were taken for nutrient analysis: nitrate, phosphate and ammonia.

During this operation, the water temperature was $0^{\circ}C$ and the air temperature was $+5^{\circ}C$. No diving equipment problems were encountered. The regulators which were used were: U.S. Divers Arctic Explorer, Poseidon and the Scubapro Mk 5. The gasoline-driven compressor was used outside. A 23-foot flat bottom canoe equipped with a 25 horsepower Johnson was used as a safety boat.

Problems

We considered that one of our major problems would be relocating the site after the ice had formed. It would be impossible to use floats and there were no trees available to take land bearings. This problem

was solved by constructing sitting points on shore using 45-gallon oil drums filled with rocks. In order to ensure that these sitting points were not removed we went on local radio and had it explained in the local newspaper.

ICE DIVING

Four ice diving operations were conducted during the months of November, February, April and June.

Transportation was provided to the work site by Bombardiers. The site was relocated by bearing and the hole was cut. The site was relocated within 30 feet each time.

Ice Cutting Equipment

Cutting an ice hole using a chain saw is probably the most hazardous aspect of an ice diving operation. Extreme caution must be used when cutting. The thicker the ice, the more dangerous it gets.

First a pilot hole was drilled a few feet away from what was to be the main opening. This provides information on ice thickness.

The aim was to finish up with a 3' x 5' hole with a step cut at one end for the diver to exit. One foot blocks were cut using the saw. They were released from the base by chipping with the ice chisel and removed from the hole using the ice tongs. This procedure was continued until we got within a few inches of the bottom of the ice. When the saw penetrates the hole floor, you must immediately evacuate the hole as the water pours in quite rapidly. The remaining 2-3 inches of ice was broken using hand augers and ice chisels. It was also found that an 8-foot length of 2 x 6 made the task of breaking the remaining ice a little easier. The floating debris was then removed from the water.

Cutting Problems

- (1) Whenever you reach a depth of 3-4 feet of ice the formation of CO and exhaust fumes of the saw increases the danger. The operator may become a little reckless so saw operators should be changed frequently.
- (2) The power ice auger which was purchased because of recommendations from reference material (Polar Diving Techniques) by Wally Jenkins was found to be much too slow.
- (3) When the temperatures dropped to a chilly -47°C , the plastic parts of the chain saw broke. The plastic handle was replaced with wood.

Clothing

- (1) Down parkas.
- (2) Waterproof insulated Farmer John overpants.
- (3) Down mitts.
- (4) Army style mukluks.
- (5) Chain saw leg guards.

DIVING

Two divers were dressed prior to departing the heated workshop. Personnel were transported to the worksite by a heated Bombardier. In addition to the two dressed divers, there was a third person as an assistant. The diver was completely dressed in the vehicle and when he left the vehicle, he immediately entered the water. He was dressed in a Unisuit and attached to a 150-foot 3/8 nylon lifeline. The standby diver remained in the vehicle. The diving times varied between 45 minutes to 60 minutes. Underwater lights were used during the darkest periods in November and February.

Problems

- (1) At -47°C the Unisuits set hard and the diving hoses went rigid. Great care had to be taken so as not to expose them to the extreme cold for long periods.
- (2) The regulators were not used until the diver submerged because of the problem of free-flow in the second stage.
- (3) During the darkest periods in February and May, the visibility was restricted so that underwater lights were required in order to complete the underwater work. Six volt underwater lights and cyanalumes were used to illuminate the writing boards.
- (4) Regulator icing was minimal in the 2nd stage. However, there was some free-flow after 40-minute dives. The 1st stage became covered with an ice ball approximately 4" in diameter during the coldest period. This did not alter the breathing but it made it impossible to remove the regulator from the cylinder until the ice melted.

- (5) There were no problems encountered with the Pursuit valves.

OTHER PROBLEMS

In the Arctic, surface activities can be hazardous and difficult. One has to be constantly alert and a high state of physical fitness is extremely important.

Skilled drivers only should be used in operating Bombardiers or other land vehicles. This is particularly true during the spring when the snow begins to soften. It is quite easy to get stuck in deep snow.

When conducting winter diving operations, it is essential to have either a heated vehicle or a heated building at the dive site.

It was discovered that the gasoline-driven compressor was not suitable for charging the diving cylinders during the extreme cold winter temperatures. The gasoline engine was changed to a 115V AC electric motor. 220V AC is not easily available.

One must constantly be on guard to ensure that you do not succumb to frostbite. Adequate clothing should always be worn. Even if you venture outside for a few minutes, the cold temperature combined with the wind can freeze your skin within minutes.

When flying in the Arctic you should always wear adequate clothing and carry your sleeping bag with you. It is not uncommon to be stranded. You might find yourself sleeping in an unheated one room airport.

When making your plans, you should always allow a few days for a storm. This is particularly true when flying away from the jet route using propeller-driven planes and non-controlled airports.

SCIENTIFIC RESULTS

- (1) Kelp production is relatively small in spite of apparently large beds of plants. It is 10% of Nova Scotia's production.
- (2) No kelp growth occurred during the ice-free period because of the nutrient deficiency which occurs during the summer.
- (3) Rapid growth begins in February and ends in April and May.
- (4) Plants are very long-lived, up to 12 years but very slow like Arctic char - so presumably any disturbance in the marine ecosystem would mean a very slow recovery rate.

The scientific details are being published in a separate paper.

MAN UNDERWATER, MEDICINE AND MIRACLES - II

By

Dr. M. Lepawsky

Cancer and decompression sickness have generally got nothing to do with each other. Individually, nonetheless, they both recently tried to do in a diver. He, not to be undaunted, is still diving. Therein lies a tale.

The diver is 167.64 cm tall and weights 79.43 kgs. For the English amongst us this means he is 5 ft. 6 ins. and 174-3/4 lbs. He is in his mid-30's. He smokes, cigarettes mainly, as many as 100 or more per day and inhales deeply. He dives for a living. He is married and has two children.

Let me observe here, the more one smokes, the more likely they are to develop certain cancers. The same formula does not apply to diving and decompression sickness. One may dive all they wish and not develop decompression sickness. That is assuming they follow strict safety precautions. These precautions are well known to most divers. But try as we will, the diving community has not been able to convince everyone that if strict, safe diving protocol is not followed, then decompression sickness can and will occur.

The diver in question has a known history of smoker's bronchitis. He had active bronchitis and sinusitis and was taking non-prescription drugs when he did the dive that produced this bend. His dive was to 164 ft. for 28 minutes. He did not inform his diving supervisor of illness and he responded negatively to his pre-dive check including questions relating to health.

He reported initial sinus squeeze when he took his properly delivered surface decompression, but this cleared. Five and one-half hours after he came out of decompression he was on his way to the beer parlour when he began listing to the left. Later, he seemed to have trouble passing water. He reported his signs and symptoms twenty-four hours later and was given recompression, properly, on the spot.

Transported to Vancouver, he was seen and had some coarse sounds in the lungs, left leg and arm weakness and cloudy sinuses. In consultation with other physicians it was found that he had a small area in the lower left lung which had delayed gas exchange on xenon gas washout lung scan.

This first slide shows this area...here. The second slide shows the timing of this series. The third slide shows the nuclear medical specialist's interpretation of this study.

Clearly, what had happened in simple terms was that impaired gas exchange had produced slow enough nitrogen blowoff and gas trapping that decompression sickness resulted. Had this diver not smoked in the first place, and if he had admitted his sickness and non-prescribed drugs, he could have avoided his incident entirely.

His recovery was really quite adequate and this next slide shows normal symmetrical gas uptake and blow off bilaterally. The next slide shows the timing of this series. The following slide shows the interpretation of this study by the nuclear medical specialist.

He is well motivated and plenty strong. He wanted to dive again. Ultimately he regained full strength because of hard work at physiotherapy. He was cleared by specialists and returned to diving.

This spring, he came down with the flu. Everybody who worked where he did seemed to get it. His did not go away and he was sent out of his work area, went home and was put on treatment by his family physician. He didn't get better and came back to see me.

He had bronchitis again for sure, plus something else. We had to change his medicines and start tests on him. This time sputum analysis showed Class IV malignant cells as this slide shows. This may as well be a clear cut diagnosis of bronchogenic carcinoma, the second largest killer on the North American Continent. Second only to heart attacks.

The next slide shows an example of the abnormal cells which were reported at low power. The next slide is a high power view of an atypical cell. Then a slide showing atypical cells at low power. Following that, another two slides of atypical cells at high power. Such cells were present on each of three separate specimens collected on three separate days.

Well, he had to be informed of the findings and it scared him enough to almost quit smoking. He continued the new medications and was sent back to a specialist. Repeat sputa studies were initiated and to everyone's delight, they came back Class I or normal. The next slide shows the subsequent report of the normal cells obtained on this man's follow-up studies. The next slide shows an example of normal cells as seen at low power. Next are two slides showing low and high power views of a normal cell obtained on this man's follow-up studies. Each of three separate specimens collected on three separate days showed only normal cells.

This was not quite adequate so a bronchoscopy was performed. To do this a small tube with mirrors and lights is used to look inside the lungs. This study was also normal or at least no area of cancer was found. The next two slides show the report and results of this study.

Right, well ultimately after repeat sputa studies continued to reveal Class I or normal cells, and normal lung function tests, this man was cleared first for diving to 2 ATA and ultimately for unrestricted diving activity. What else he might come up with is not known. It is suspected he still smokes, though he knows he shouldn't. There is plenty at stake...his life, his career and his family.

This case history to me is truly miraculous and shows what decompression sickness and cancer have almost done to one individual. He survived both up to this point, and God willing, will continue to do so. The case shows the inherent dangers involved in diving without adhering to the specific known rules of diving safety.

It is my hope that such contravention of safety procedures will stop across the board. It may seem reasonable enough to think this may be the case. But a recent case of Type II decompression sickness with spinal cord involvement has me worried.

In this case, a commercial diver was working for a small and little known diving company in north-west British Columbia. He was sent to more than 150 ft. on air for a confused amount of bottom time, but certainly long enough to require decompression. This was in specific disregard for WCB Regulations and in spite of specific WCB denial of permission to perform a decompression dive. The diver was definitely shorted on decompression time and he developed chest pain before surfacing. He could not walk and had no bladder control once he surfaced.

Ultimately, he was treated at the Vancouver General Hospital Hyperbaric Unit. After recurrent, prolonged, therapeutic hyperbaric oxygen exposures he is presently walking and has urinary control. For those who are wondering what other functions have returned, let me assure you he keeps his fiancé very happy and vice versa.

But there are other concerns in this case. First, will the diver fully recover? Unknown. Second, will the diver ever again be able to dive recreationally, let alone commercially? Unknown.

Third, and more important, the employing company is apparently still in business and likely to try to operate a recompression chamber with 9 ATA capability! Mind you, this company has never owned or operated a recompression chamber in the past. So the fourth concern becomes, what will happen to other employees of this company?

The Vancouver General Hospital Hyperbaric Unit is preparing for more cases of decompression sickness.

The diving community must police itself or get policed from outside. I hope we can do it for ourselves. But if it is ignored, what can happen when safe diving practices are not followed, then as a

community we shall be penalized.

Last year increased underwater work showed promise as a cure to unemployment, inflation and all kinds of social ills. This year it still has that promise in spite of the two previously mentioned cases.

Let me dramatize what promise underwater work holds. In the Arctic this year there have been almost twice as many diving hours as the year before. In spite of that, the total number of bends cases has remained about the same! Touch wood quickly.

This stands in contrast to other more accident prone areas of the sea and it is a credit to the diving community. There is no intention that the diving community should rest on its laurels where safety is concerned! The majority of commercial diving firms rigorously pursue safe diving procedures to the utmost. Let's just make sure that applies across the board.

Actually there should be concern for what is happening in the sport diving community. Recently, a supposedly ex-commercial diver who had not dived for about one year took double, steel eighties for deeper than 150 feet of sea water to get anchors off a cable. He had 2200 lbs of air in them. Becoming narcotized and disoriented he overstayed no decompression limits badly. He tried to decompress in the water. He was having severe trouble before surfacing. Ultimately he was hovercrafted and ambulated to the Vancouver General Hospital Hyperbaric Unit.

Initially, he was paralyzed from the neck down. He is receiving recurrent hyperbaric oxygen treatments. At first, he required assisted breathing. Presently, he is breathing on his own and some motor control is returning. He has a long way to go to full recovery but he seems full of fight and hopeful. These last two qualities are all in his favour. He has a lot to shoot for, too. His family, a wife and four children, his ability to work.

This case represents clear cut disregard for diving safety. The victim himself has said so. He had no diving buddy, no depth gauge, no watch, no compass. He was badly out of shape. In short, he had no business making the dive he did.

This kind of ill-advised activity has got to stop unless we are prepared to have others do our thinking for us.

Mind you, I still hold that underwater work holds more potential than what is presently recognized. Look at space budgets. Great! To this stage, the return payload has been about nine hundred pounds of rock.

Compare that to 12,000 barrels per day of oil in the Beaufort or whatever the combined output is from the North Sea.

No sir! The first human foot print on the moon isn't going to help the third world very much to stop starving. Not that I begrudge old Armstrong his "small step for man". (slide of first footprint of man on the moon).

I don't. Not at all. But let's stick to basics. (Slide of Aldrin coming off ladder).

Here we are (Slide of Earth).

There's Vancouver Island. (Slide of Vancouver Island).

That's the Vancouver General Hospital Hyperbaric Unit (Slide of VGHIBU).

Let's get the money to the diving community so they can keep at work...safely!

So much for Mankind Underwater. So much for Medicine. So much for Miracles. And so much for my address to the Fourth Canadian Diving Symposium.

I thank you.

OCCUPATIONAL HEALTH AND SAFETY

By

Mr. J. KingCanadian Centre for Occupational Health and SafetyTHE CHALLENGE

Ensuring that work is respectful of human life through advances in occupational health and safety is a matter of great concern in Canada today. While there is little disagreement with the concept that all Canadians have a right to a healthy, safe, work environment, achievement of that goal still lies in the future.

Each year, the best available statistics show that more Canadians are injured or made ill at work and the severity of those illnesses and injuries increases. There are no standardized, cohesive records or statistics in existence to provide the total picture, particularly with regard to occupational diseases.

Little research is done in Canada on occupational hazards yet it is estimated that at least 200 new health problems arise each year in the work environment. In some ways Canada is ill-equipped to meet the challenge for change in these areas because of a lack of professionals in occupational health and safety.

Progress is also made difficult by the multiplicity of agencies working in the field with little or no co-ordination--some 400 public and private groups. The jurisdictional area alone is fraught with complications. There are hundreds of laws and regulations, both federal and provincial and these are administered by a great number of different departments and agencies.

The wealth and diversity of activity shows that concern is widespread but more extensive knowledge and greater collaboration can turn that concern into significant and progressive accomplishment.

THE CENTRE - PURPOSE AND PRINCIPLES

The basic purpose of Canada's first national Centre for Occupational Health and Safety is to promote, through co-operative activity, joint planning and the dissemination of information, the physical and mental well-being of Canadians at work. Another feature of the Centre will be an undertaking to provide the Canadian community with a better understanding of the effects on people of work and work environments in their beneficial as well as their harmful qualities.

The Centre is an independent, self-governing body. It reports to Parliament through a Minister but is part of no government department or agency. It exists to provide a common focus and impetus for activity and progress in all areas of occupational health and safety.

Three main principles guide the Centre's work: the desire to work openly and provide information freely; to support research in order to provide facts without value judgments and to maintain its independence so that it may speak out strongly on vital issues.

OPENNESS OF INFORMATION AND PUBLIC ACCOUNTABILITY

The legislation authorizing creation of the Centre includes the following specific points concerning the Centre's role in the provision of information on occupational health and safety. That the Centre:

- a. establish and operate systems for recording, analyzing and disseminating information;
- b. publish and disseminate scientific, technological and other information. All reports of research supported by the Centre must be made available within 90 days of receipt of such reports;
- c. provide advice, information and service on health and safety problems to workers; trade unions; employers; government; national, provincial and international organizations and the public;
- d. sponsor and support public meetings, conferences and seminars;
- e. consider briefs and representations submitted to it and account each year for its action or response to such briefs.
- f. submit a report of its activities annually to Parliament at the same time as it is forwarded to the Provinces and Territories.

These six points, underline the requirement for the Centre to provide information to the public, to respond to the needs of Canadians and to be accountable to Canadian taxpayers. They also show that one of the Centre's main activities is the collection, evaluation and dissemination of co-ordinated information on occupational health and safety. This means that the Centre must initiate studies to fill gaps in existing information. For instance, studies that provide for record exchange so that connections can be made between exposure to hazards and subsequent disease or death.

THE RESEARCH -- FACTS WITHOUT VALUE JUDGMENTS

The legislation provides that the Centre:

- a. promote, assist, initiate and evaluate research.

Canada is behind in research on work hazards, the development of warning systems and of remedial measures. There is no lack of vital research work that the Centre must stimulate and support. Wherever possible this is done in co-operation with existing research capacities.

In order to avoid duplication, and foster better utilization of our limited resources, the Centre must undertake a review process of research projects related to occupational health and safety.

Since reports of any research supported by the centre must be released, the availability of research results is guaranteed. The results are made available with or without consensus of the Centre's governing council and await no government approval.

The reports that the Centre issues must be factual and without the value judgments of particular interests or of any jurisdiction. They put forward the best existing knowledge on any hazard or problem area. Facts must be known first then disseminated and value judgments must come afterwards.

In many instances the Centre's work can lead to the publication of criteria documents aimed at stimulating standard setting action by the appropriate jurisdictions. Such documents are also openly available.

CANADIAN EXPERTISE

The legislation states that the Centre:

- a. support and facilitate the training of personnel in and for occupational health and safety;
- b. give recognition to individuals and organizations for outstanding contributions to the field.

In order to meet its basic objective of promoting the fundamental right of Canadians to a healthy, safe work environment, the Centre concerns itself with the stimulation of human resource development in the field. In co-operation with existing educational institutions, the Centre will undertake specific activities to increase Canadian expertise in occupational health and safety.

THE STRUCTURE--INDEPENDENCE AND PARTICIPATION

To carry out these activities and to ensure its independence and non-biased nature, the Centre has a governing council of 39 members as follows: 10 representatives nominated by the lieutenant governors in council of each of the provinces; two chosen by the commissioners of the territories; four from federal departments and agencies; 11 selected in consultation with workers' organizations and 11 selected in the same manner representing management organizations. The Chairman, as well as all other members of this Council, will be appointed by the Governor in Council.

The Council, which meets at least three times a year, appoints advisory committees, such as scientific and technological committees, to support its work.

The President, the full-time chief executive officer, chairs the Executive Board which meets not less than six times a year. The Board is chosen from and by the Council. It has an equal number of members representing workers' organizations and management organizations and they comprise fifty per cent of the Board's membership.

The permanent staff of the Centre is small and will continue to be so--perhaps numbering about 85 people after three to four years operation. The staff includes specialists in health, engineering and other pure and applied sciences as well as safety and information specialists. They are not part of the Public Service. Experts are drawn in to participate in particular projects without becoming permanent staff members.

The Centre has no regulatory powers and does not compete with any jurisdiction but exists to serve all. The excellence and credibility of its work is the only authority it has. Its qualities of independence and openness enable it to provide the atmosphere for to-equal partnership and the sharing of ideas amongst all the participating groups.

THE ORIGIN

Ultimately, the key to achieving the purpose for which the Centre was established lies in the interest, support and participation of individual Canadians. Equipped with authoritative information, the individual worker and his or her employer can become more active participants in controlling or removing hazards in their own place of work as partners with the appropriate jurisdiction or administering authority.

Production of goods and services creates occupational hazards but by working together ways can be found to control or eliminate those

hazards. Work can and must respect both the physical and mental health of all workers. It is to this challenge that the Centre is dedicated.

DCIEM DIVING PROGRAM 1979ByLCdr B.A. Ridgewell, DCIEMINTRODUCTION

The Canadian Forces and DCIEM have one research and development program associated with man-in-the-sea. This R and D program is called "Man Underwater" and is organized in the following sub-programs:

- a. Diver Systems and Techniques;
- b. Submersible Systems and Techniques; and
- c. Diving Biomedical Research.

This paper will discuss sub-programs a. and b. and Dr. Kuehn from the Biosciences Division discussed sub-program c. in his "Overview of DCIEM Research and Development in Support of Canadian Diving Operations" presented on the first day of this conference.

DIVER SYSTEMS AND TECHNIQUES

The Diver Systems and Techniques sub-program emphasis is on test and evaluation and development of diver equipment prior to acceptance and procurement by the Canadian Forces. At present, the following five projects are being actively pursued:

- a. CABA Diving Systems;
- b. SSBA Diving Systems;
- c. CCEA Diving Systems;
- d. Hyperbaric Systems; and
- e. Operational Decompression Computer Techniques.

CCEA Diving Systems. The Compressed Air Breathing Apparatus (CABA) Project Team is tasked and separately funded by National Defence

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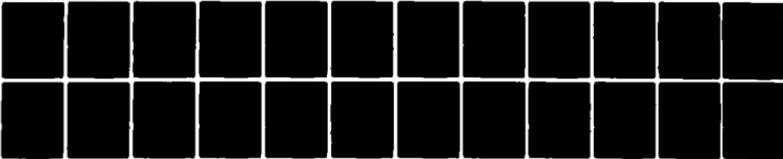
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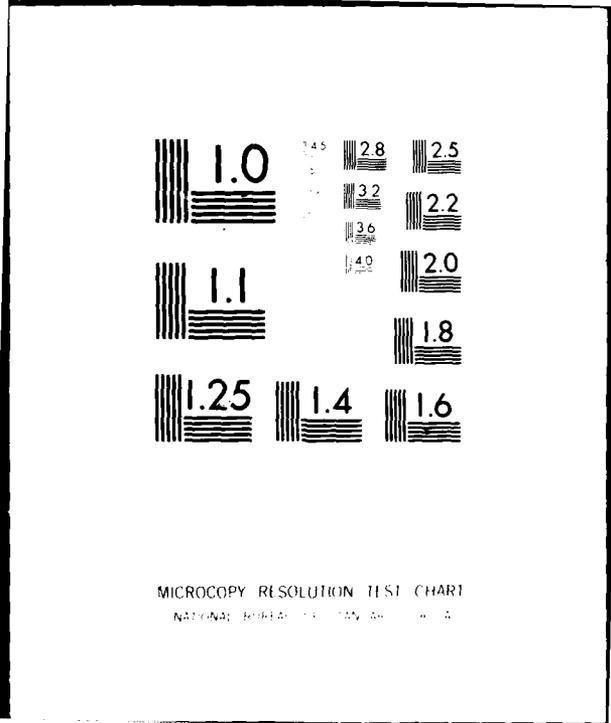
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Headquarters (NDHQ), Directorate of Maritime Electrical Engineering (DMEE). This NDHQ (DMEE) task is "to investigate improvements to the safety, reliability, maintainability and performance of CF CABA diving equipment".

Last year 800 Scubapro Mk V single hose regulators were purchased to replace our aging double hose regulators and issued to the operational units. During the first winter of operations a number of freeze-up problems with these regulators were reported. In May of this year, extensive testing of freeze-up modifications to these regulators were conducted and resulted in the recommendation that silicone grease and a replacement first stage cover be purchased for these regulators. This modification should solve 60-80% of our freeze-up problems. The other 20-40% freeze-up problems that occur in the second stage of the regulator is a little more difficult to solve, however we are looking at plastic coating of parts and methods of preventing water from getting into the second stage.

Some progress has been made with our high pressure tubing gas reservoir, Industrial Research (IR) contract. The thin wall aluminum tubing has been heat-treated and work-hardened to withstand pressures in excess of 8000 psi. Using a 2:1 safety factor, this tubing can now hold pressures to the maximum output (approximately 3000 psi) of our H.P. compressors. An extensive mechanical testing program is planned for this year to determine the minimum bending radius, the best configuration and optimum gas stowage pressure. Considerable work on this concept is still required, however, the potential rewards of improved diver comfort and the additional safety of high pressure storage in properly selected HP tubing, warrants continued research and development of this concept.

This project team has been active in upgrading our wet suit specifications. Numerous questionnaires and letters have been sent to various Canadian suit manufacturers and as a result of their comments, our suit specifications are just about complete.

Work is progressing in the sports diver version of the DCIEM Decompression Computers. The prototype XDC-3 Decompression Computer will be evaluated during the next year to determine the operational envelope of the computer and the reliability of the electronic components. DCIEM is planning to develop a simple digital depth gauge by an IR Contract, possibly using some components developed for the XDC-3.

SSBA Diving System. The Surface Supported Breathing Apparatus (SSBA) Project Team is tasked and funded by NDHQ (DMEE) "to investigate and recommend methods of improving the safety, reliability, maintenance and performance of umbilical or surface supported breathing apparatus for the Canadian Forces".

It was mentioned last year that the Oceaneering International "Rat Hat" had been selected for procurement by the Canadian Forces. Initial procurement tenders received from Oceaneering were unacceptably high, consequently, the SSBA project team was tasked to conduct a quick survey, then test and evaluate any suitable off-the-shelf demand breathing helmets. The survey revealed that the Diving Systems International (DSI) "Superlite-17B" helmet appeared to meet our system specifications. From mid-February to the end of March 1979, three Superlite-17 helmets were extensively tested and evaluated at DCIEM. The helmet demand system provided surprisingly low inhalation and exhalation resistance in moderate to heavy and excessive work rates and was well within DCIEM acceptance standards. Some deficiencies were found in the regulator and the overall buoyancy of the helmet, however, none were deemed serious enough to reject it as a serious contender. The deficiencies have been reported to DSI and corrective action is being taken. An operational evaluation of the Superlite-17 was conducted at the Fleet Diving Unit (Atlantic) earlier this year and the helmet was well received. Both the "Rat Hat" and the "Superlite-17B" will meet our helmet specifications and it is likely that one will be selected and purchased for the Canadian Forces this fiscal year.

A neoprene dry suit to interface with the Rat Hat was developed, specifications drafted and a contract awarded. The problems with the helmet selection has resulted in a hold on the completion of the neck area of the suits. At present the SSBA Project Team is developing various suit to helmet interface pieces to accommodate whichever helmet is purchased. We are also investigating various suit supply and exhaust valves and some development contracts may be awarded if suitable valves cannot be found. Hot water suits and boiler systems have been purchased to interface with either helmet that is selected.

A unique composite umbilical comprising two 3/8" I.D. hose, one 1/4" I.D. pneumo hose and a 1/2" I.D. electrical cable all twisted together to make a 2" diameter umbilical has been selected for the SSBA diving system. This umbilical is manufactured in the U.K. by Pneu

Hydraulics and comes complete with a toxicological gas analysis of each length of hose. Gas analysis of sample lengths of hose conducted by DCIEM support the analysis of the manufacturer and in all cases the umbilical is well with CF specifications.

A gas and electrical slip ring and umbilical stowage drum has been purchased from Nova Scotia Research Foundation to stow our composite umbilical on. This unique electrical slip ring and rotary connector will be evaluated during this next year, however, initial indications suggest that this concept may solve our umbilical stowage problems on our small diving tenders.

Air and mixed gas consoles designed and built by DCIEM have been delivered to the Fleet Diving Units and HMCS CORMORANT. For diver communications, the Helle 3340 was selected and purchased for the Canadian Forces. For internal helmet communications, the Helle system and other commercial speakers and microphones were rejected in favour of a Carter Engineering M101 microphone and preamplifier and H-143/AIC speakers. This new helmet communication system was designed by DCIEM and is superior in quality to all other systems tested. With minor modifications, this system can be used in all CF helmets and masks presently in service.

The DCIEM XDC-2 Computers are currently undergoing technical and operational evaluations. Numerous modifications have been made to these units to correct some component deficiencies, however it appears that these units will be issued to Fleet Diving Units and HMCS CORMORANT by the summer of 1980.

CCBA Diving System. The Closed Circuit Breathing Apparatus (CCBA) Project Team has been tasked and funded by NDHQ (DMEE) to find a replacement for our aging CDDBA diving set by 1982. A rapid world-wide survey of suitable mine countermeasures (MCM) diving sets was completed last year. The survey concluded that the constant PO₂ USN EX 16 and the Swedish AGA Mixed Gas MCM diving sets should be extensively evaluated.

An IR contract to develop a novel constant PO₂ semi-closed circuit MCM diving set is being processed through NDHQ at this time. This concept is unique because it is simple, therefore it should be reliable, easy to maintain and inexpensive to manufacture. Our plan is to monitor the USN development of the EX 16, evaluate the AGA Mixed Gas Set and proceed with our own development set so that by 1982, a suitable MCM diving set can be selected for the CF.

Hyperbaric Chamber Systems. DCIEM is not tasked directly to provide technical hyperbaric engineering support to NDHQ (DMEE). A tasking in this area had to be turned down due to insufficient manpower. Mr. J. Sherwood was hired by NDHQ to provide this technical support and placed here because of the hyperbaric expertise available in DCIEM.

An extensive modernization program is underway to outfit all CF hyperbaric chambers with improved chamber lighting, communications, BIBS systems, overboard dump regulators and standardized consoles. These consoles will include the XDC-2 Decompression Computers and DDL-1 Data Log Cassette Recorders.

The DCIEM 340 fsw hyperbaric chamber will similarly undergo a major refit this next year. In addition to upgrading of these main hyperbaric facilities, four new two-man Draeger portable treatment chambers are being purchased for fly-away and remote diving support.

Operational Decompression Computer Techniques. The Surgeon General has tasked DCIEM "to determine the safe operational envelope of the XDC-2 decompression computers and their suitability for operational use".

A series of bounce dives were conducted in June and July of this year in the depth range of 36 to 54 msw. A second series is planned for this November. The Phase I dives were highly successful and provided DCIEM with considerable insight into decompression stress and the relationship between the DCIEM decompression computers and various other air decompression tables. A major portion of the success of Phase I was due to the ultrasonic doppler technique of monitoring venous gas emboli (VGE) in the pulmonary artery of the dive subjects during decompression and for many hours after surfacing. During Phase I, nine Type I (pain only) cases of decompression sickness (DCS) were recorded in a total of 102 man-dives. The ultrasonic doppler monitoring technique clearly provided a more accurate and acceptable means of detecting decompression stress in dive subjects by monitoring VGE rather than relying on the traditional empirical method of deliberately provoking DCS (bends). By this time next year we should have some interesting results to report.

SUBMERSIBLE SYSTEMS AND TECHNIQUES

The Submersible Systems and Techniques sub-program is new and has been fostered by recent developments in Submersibles, Atmospheric Diving

Systems (ADS) and Remotely Operated Vehicles (ROV). The purpose of this sub-program is:

- a. to evaluate AD Systems available to DND;
- b. to conduct manipulator R&D; and
- c. to investigate ROV Systems.

Atmospheric Diving Systems. DCIEM is tasked by the Maritime Commander "to investigate various AD Systems and evaluate which systems are best suited to DND requirements". It is our intention to monitor the RN and USN evaluations of JIM and SAM AD Systems. DCIEM has conducted a preliminary evaluation on the OSEL MANTIS ADS from U.K. The MANTIS concept demonstrated considerable potential as a seabed work vehicle. As a result of this initial evaluation, funds were identified and negotiations were started with the intent of purchasing a MANTIS from OSEL last fiscal year. Regrettably, the negotiations failed and the opportunity to purchase the MANTIS X-4 was lost. Fortunately, the concept is strongly supported by NDHQ, consequently, an IR contract to design and build a one man submersible with force feedback manipulators and remote operating features will be submitted to NDHQ in the near future.

Manipulator R and D. The major weakness of submersibles and AD systems is the limited dexterity of the manipulators on these vehicles. For this reason, DCIEM has been tasked and funded by NDHQ (DMEE) to develop low-cost force-feedback manipulators for use with small submersibles. A four function and a seven function hydraulically operated manipulator of the current state-of-the-art has been purchased from International Submarine Engineering for evaluations. Because of their modular construction, these manipulators are readily adaptable to the CF submersible SDL-1, as well as smaller submersibles and our testing facilities.

Remotely Operated Vehicles. Remotely Operated Vehicles (ROV's) will be investigated in the near future to determine their suitability to the Canadian Forces. There can be no doubt that they have considerable potential in seabed search/survey roles.

SATURATION DIVING PROGRAM

Exercise CETPE. DCIEM is not tasked by NDHQ to conduct a saturation diving program. Consequently our efforts in this area are generated in-

house. An exercise called CETPE for Chamber Equipment Testing and Procedures Evaluation was organized and carried out in January of this year. This exercise was a seven-day, one atmosphere dive for four dive subjects: to evaluate the operational and functional aspects of the facility; to train the Diving Division personnel on the safe operation of the facility; and to establish scientific base line data on psychological stress due to confinement, sleep studies, physiological and thermal monitoring, breathing resistance including CO₂ levels and heart rates, and the general habitability of the facility.

In general, CETPE was highly successful. The habitability of the facility was found to be excellent with only minor modifications to some furniture required. The life support system functioned extremely well with: the CO₂ levels never exceeding 0.1 per cent surface equivalent; noise levels did not exceed 65 dbA; and the relative humidity was maintained easily at 60 \pm 10 per cent. It was generally agreed by all that the atmosphere inside the facility was more comfortable for the divers than it was for the watch keepers on the outside .

All dry scientific experiments were successful in collecting base line data and the underwater experiments using the ergometer were equally successful. The general result of Exercise CETPE was that there was no decrement in performance in any of the dive subjects due to the confinement of the facility.

CONCLUSIONS

It should be readily apparent that the Diver System and Techniques sub-program has been quite active during this last year. As a result of this work the operational divers of the Canadian Forces will be outfitted with the latest state-of-the-art diving systems available, during the next few years. The Submersible Systems and Techniques sub-program is just now getting started. It is believed that this sub-program will compliment our DDF Saturation Diving Research Program and ultimately result in operational equipment that will significantly enhance our Canadian Forces sea bed work capability.

The "Man Underwater Program" is an ambitious research program which is being expanded in scope at DCIEM. We are indeed fortunate in having some of the finest hyperbaric facilities in the world, however, our greatest asset is the close working relationship which exists

between our multi-disciplined personnel. The formation of project teams that span the scientific, engineering, medical and operational disciplines has been the secret of our success to date and will continue to be so in the future. We intend to make significant contributions to enhancing the performance of man in the hyperbaric environment.

A REVIEW OF THE USES AND DEVELOPMENTS
IN REMOTELY OPERATED UNDERWATER WORK VEHICLES

IN CANADA

By

Mr. D.R. Huntington
International Submarine Ltd.

INTRODUCTION

Since the last Canadian Diving Symposium many advances have been made in application of Remotely Operated Underwater Vehicles (R.O.V.'s). The Canadian company International Submarine Engineering Ltd. (I.S.E.) of Port Moody, B.C. is playing an active part in this development. Many ideas and concepts have been converted into realities and the ROV's are now performing more and more tasks which originally required a man on the sea bed. The innovation in this sector of industry is being stimulated by government policy and plain economics.

The R.O.V., now a sophisticated and technologically advanced off-shore tool performs a wide range variety of inspection, survey, support and other tasks under water. A recent survey showed that underwater vehicles can perform 70% of the tasks previously accomplished by divers. These work systems do almost anything not requiring on-site applications of special skills, such as welding.

Increased limitations on diver capability from hostile environments, water depths, and more stringent regulations, means the alternate work systems will be called on more frequently in the future.

This article briefly covers: -

1. Technical Description of R.O.V.'s,
2. R.O.V. Capabilities and Review.
3. Future Developments.

TECHNICAL DESCRIPTION OF R.O.V.'s

Most R.O.V.'s consist of the following common basic components:

- a. Flotation Package;
- b. Propulsion System;

- c. Control System;
- d. Umbilical;
- e. Surface Control System;
- f. Ancillary Gear.

FLOTATION

Syntactic Foam is commonly used as a media to provide buoyancy. The volume of the foam package increases with vehicle complexity and dive depth. Generally speaking, the vehicle designer will aim for a neutral condition of buoyancy. Any additional material will be added to provide payload or slight degrees of positive buoyancy.

PROPULSION

Thrusters are provided to give the R.O.V. motion in the vertical, lateral and fore and aft directions. Their size is determined by vehicle size, dive depth, umbilical size and expected operational conditions such as currents. Speed is not often a feature for consideration. Both hydraulic and electrical thrusters are available. Electrical are used more because of their high system efficiency; they offer a low acoustic noise level, they are easy to change in the field and lastly, each thruster is independent of the others so that a single failure does not affect the performance of the others.

CONTROL SYSTEM

The basis of all control systems is the multiplexing of the vast amounts of data required. The command information is all multiplexed. The intent of multiplexing is to transmit the appropriate downlink and uplink information to the desired sub-system. Basic multiplexing telemetry control is based on COMPLEMENTARY METAL OXIDE SEMICONDUCTOR (C-MOS) technology and for the time being, this is adequate for the majority of control systems. However, the future will see increased use of MICROPROCESSOR control as the demands on R.O.V.'s increase. The three basic components of a telemetry system are:-

- a. Coding unit;
- b. Decoding unit; and
- c. Interconnect wire in umbilical.

UMBILICAL

The umbilical provides a power and control link to the R.O.V. As transmission capacity is increased, the diameter is increased, hence

drag is increased. The packing configuration can consist of twisted shielded pairs, coaxial cables, power conductors and stainless steel braid around the outside to provide strength.

Umbilicals offer various disadvantages to R.O.V.'s.

- a. they create drag;
- b. they limit the vehicle operating radius;
- c. they are subject to entanglement;
- d. they compromise the safety of the vehicle and its possible recovery when severed.

SURFACE CONTROL SYSTEMS

These vary in complexity depending on the overall capabilities of the R.O.V. system. A system for a small DART is contained in a suitcase whereas a TROV system can often require a 20-ft. container with computers, instrumentation and controls. The following items are present in all systems.

- a. Pilot's Controls for propulsion, ballast, manipulators, etc.
- b. Video Controls for pan, tilt, focus, and switching between cameras;
- c. Vehicle information as to depth, heading, altitude, etc.;
- d. System Power Control;
- e. Readout and recordings for special tooling.

ANCILLARY GEAR

This category includes generators, handling systems, floatation packages, umbilical winch, navigation positioning systems, surface positioning equipment etc.

R.O.V. CAPABILITIES

R.O.V.'s can perform a wide range of survey inspection, testing, and work tasks under various environmental conditions, relatively independent of water depth. With this broad potential, combined with unlimited duration, operating safety and cost-effectiveness, the R.O.V. is a growing factor offshore.

R.O.V.'s can be used for the following operations:-

- a. Route surveys and inspection;
- b. Support of platform setting;
- c. Support of subsea completions, tie ins, repairs;
- d. Inspection of platforms, risers, pipelines, etc.;
- e. Location and recovery of subsea obstructions;
- f. Side Scan and Sub-bottom information;

- g. Prelay, lay and postlay support of pipelining operations;
- h. Trenching, preburial, postburial support of pipelining operations;
- i. Support of diving operations;
- j. Debris clearance;
- k. Operation of Subsea valves;
- l. Remove and replace guidelines;
- m. Attach heavy lift cables;
- n. Underwater cutting;
- o. Placement of explosives;
- p. Structure cleaning;
- q. Non-destructive testing;
- r. Measurement of cathodic potential;
- s. Jetting and burial;
- t. Inspection of dams;
- u. Inspection of the inside of pipelines;
- v. Drillship support activities;
- w. Mine neutralization missions;

- x. Mine hull surveys;
- y. Under ice surveys;
- z. Bottom sampling.

This list is broad based and covers many applications. There are many other applications which could be added; these are constantly expanding.

PIPELINE INSPECTION

Early in 1979 InterSub of France committed to convert a submersible handling ship INTERSUB 5 to accommodate an I.S.E. TROV R.O.V. InterSub 5 can also accommodate a manned submersible for back-up purposes. The new system was installed and successfully trialed in the North Sea.

TROV S-8 is outfitted with the following equipment:

- a. An InterSub Development Pipetracker;
- b. Sensor package capable of providing depth of cover and trench profile;
- c. Auto Pilot;
- d. Auto Depth Control;
- e. Altimeter;
- f. Scanning Sonar;
- g. T.V.;
- h. C.P. Probe;
- i. Seven and Four-Function Manipulators;
- j. R.O.V. Tracking System;

InterSub 5 is outfitted with the following equipment:

- a. Dynamic Positioning Control (D.P.);
- b. TROV Handling System;
- c. TROV Umbilical Winch;

- d. Navigation Interface Equipment allowing the TROV to navigate the InterSub 5;
- e. TROV Control Room which houses Pilot's Control, Navigator's control and remote umbilical winch control;
- f. Computer Room which computes all data on up-traffic from TROV and gives a real-time readout on a graph of the buried pipeline condition and environmental conditions.

This system is limited by system reliability and weather only. A well established system in a good weather window could continue operating indefinitely.

Diver Support

A growing use of R.O.V.'s is in the support of diving operations. Before the diver enters the water, the R.O.V. surveys the job site. This helps maximize the divers' bottom time. When the diver is in the water the R.O.V. provides lighting and a means of monitoring the divers' progress.

A dramatic application of this type came in June of this year in the Campeche Sound of the Gulf of Mexico. The semi-submersible rig Sedco 135 was drilling in PEMEX's IXTOC 1 well when a blowout occurred. The pressurized oil and gas began escaping from the riser connector on top of the blowout preventer which was inoperable. The well site was located in 150 ft. of water about 50 miles offshore.

Martech International of Houston were called in to assist in surveying the damage on the seabed. They mobilized an I.S.E. TREC R.O.V. which was driven in close to the well and the base of the VORTEX of the blowout. Excellent video recordings were provided by TREC which assisted decision making by a crew headed by Red Adaire of Houston. TREC stayed on site while divers attended the B.O.P. to attempt repairs.

Drillship Support

During this summer Can-Dive Oceanering of Vancouver, B.C. has been operating I.S.E.'s latest TROV, the S-9, aboard the deep drillship BEN OCEAN LANCER on charter to AQUATAINE. This spread was located in the Davis Strait off Canada's eastern seaboard. Operating through the moonpool, typical duties include inspection of the drillstring to the seabed, inspection and repair of the B.O.P. stack, advice to drill operators for locating the drillstring and bottom debris clearance. TROV provides real-time T.V. to the drill team. This is the first time that an R.O.V. has been used for this application from a drillship.

To date, support of drillship operations has been offered exclusively by manned submersibles. These are dynamically positioned vessels, however, which are under close surveillance by legislative authorities due to the increase in fatalities during the last two seasons. Whilst in the water, divers or submersible personnel are reliant upon the successful operation of the complex surface ship control system and its ability to hold the ship on station. Legislation relating to such operations could cause a market increase in the use of R.O.V.'s in D.P. situations.

FUTURE DEVELOPMENTS

R.O.V.'s have performed a wide variety of tasks in support of hydrocarbon exploration, scientific and research operations and military missions. Basically, limitations of the system are related to equipment packages and the imagination of the operators. We will now consider some of the future developments which are required to meet the demands of tomorrow.

STRUCTURE INSPECTION VEHICLES

The establishment of European inspection programmes for offshore structures has created a market for underwater non-destructive testing (N.D.T.) Response to this requirement to date has resulted in submersible operators equipping diver lockout vehicles to conduct these tasks. R.O.V.'s have been equipped also with off-the-shelf equipment packaged for underwater use. Development work is being conducted in the following areas to meet this new market:-

- a. Corrosion potential measurements;
- b. Ultrasonic thickness measurements;
- c. Ultrasonic flow detection;
- d. Acoustic Holographic flow detection;
- e. Magnetic particle inspection;
- f. Magnetographic crack detection;
- g. Eddy current crack detection;
- h. Stereo and colour photography;
- i. Three dimensional enhancement of video tapes;
- j. Concrete deterioration meters;

- k. Concrete coring tools;
- l. Underwater painting;
- m. Underwater welding;
- n. Epoxy patching.

R.O.V.'s will be required to carry this equipment and accommodate data transmission links relating to the equipment. Methods of locking the R.O.V. to the structure in mid water will require further development. Self-winding metal straps and suction pads have been tested, but with varying degrees of success.

There has been a considerable interest in the last few years in developing a one man submersible for commercial use. JIM, WASP and MANTIS are examples of these. The expertise for these vehicles primarily resides in the U.K. To date, all of these vehicle types lack good mobility as well as an effective manipulative capability. They are also expensive. It is for these reasons that I.S.E. has designed a one man vehicle with superior capabilities required by industry and the military. The I.S.E. WRANGLER will complement the capabilities of the R.O.V. and will allow inspection of structure locations currently inaccessible to the manned submersible and tethered vehicle. WRANGLER has the following characteristics:

Control

Operation from the submersible or the surface. This will allow the vehicle to be used manned or unmanned. It will be possible to share control between the vehicle and the surface such as in the case where it is necessary to perform a mid water manipulative task. This effectively increases the vehicle crew without increasing the size of the vehicle. Telemetry control will reduce the number of thru hull penetrations.

Principal Characteristics

Length Overall	8	ft.
Beam	4	ft.
Height	4.5	ft.
Pressure Hull Diameter	26	inches O.D.
Ballast Tank	2	cubic feet
Weight	3000	lbs.

Diving Depth	1200 ft.
Manipulators	Two - one four-function; - one seven-function;
Propulsion	Five - 1-1/4 HP thrusters - two fore and aft - two vertical - one lateral
Umbilical	In 750 foot lengths which can be coupled for 1500 ft. length.
Windows	2 acrylic windows front and rear to give good viewing.
Payload	50 lbs. Mission Payload with a standard fit of two manipulators and a 180-lb man.
Speed Control	Single joy stick to control the speed and direction of the vehicle. Auto depth control to allow vehicle hovering.
Power Supply	Electric power will be supplied from two sources: (a) Down an umbilical (b) Battery located on the vehicle. The umbilical to provide high endurance at high power levels. The battery will provide power when the vehicle is being utilized autonomously, and when emergency power is required to operate life support and the underwater telephone.
Life Support	Oxygen and carbon dioxide scrubbing sys- tems will be provided to give 72 hours endurance.

There has been a need in the offshore petroleum industry for a relatively inexpensive, lightweight inspection vehicle which would not be able to perform inspection tasks under all the conditions of which more powerful, larger vehicles are capable. Such a vehicle would enable certain government agencies and scientific institutions which could not previously afford vehicles to be able to perform underwater observation tasks. The Deep Access Reconnaissance Television (D.A.R.T.), a new R.O.V. from I.S.E. represents an attempt to provide a capability for this market sector. The principal characteristics of DART are as

follows:

Length	40 inches
Width	18 inches
Height	12 inches
Weight	100 lbs. in air
Diving Depth	1200 ft.
Thrusters	Four - two fore and aft - one vertical - one lateral Thruster 1/2 H.P. each with 25 lbs. of thrust at each propellor.
Control	Vehicle control is located in a console which is housed in a small G.R.P. case. The console will accommodate a T.V. monitor, auto depth control, depth read-out, single stick control, T.V. pan and tilt and lighting control.
Navigation	Flux gate compass. The heading data is written onto the T.V. screen.

DART has been on trial and demonstration for the period since May this year and is proving successful. Can-Dive Oceaneering used DART on a commercial diving contract in B.C. this summer. They were called to a mill in Port Alberni to inspect the inside of the pipeline leading from an effluent tank out to sea. The pipe was four feet in diameter and it had a 90° elbow 200 ft. from the tank. Divers had originally only been able to inspect to the elbow due to umbilical restrictions. DART inspected the pipe to a point 450 feet past the elbow. The engineer was left with a video tape recording showing the pipe condition. DART prototype is currently being demonstrated to commercial diving and military authorities.

MINE NEUTRALIZATION VEHICLES

The military has a growing requirement for a task orientated vehicle for use in mine countermeasure exercises. (This is the location and disposal of foreign mines). Mines are passive, cheap, intelligent and easy to place. They offer a heavy threat to warfare at sea. The current methods of mine disposal are very heavily capitalized seagoing operations using minesweepers. Mine Neutralization Vehicles (M.N.V.) are currently being built with sonar location systems but these are very

expensive and require a tether at all times.

I.S.E. is working on the design of a low-cost MCM vehicle which could have a tether or be operated untethered. ARCS (Autonomous Remote Control Submersible) will be adaptable to other applications such as under ice work, deep ocean exploration, use as a moving sonar target, and area survey. ARCS will incorporate control by coded commands, video by slow scan, preprogrammed software to control speed, direction and tools such as manipulators, auto pilot, battery option power, sonar scanning for mine location, variable buoyancy to account for weight changes underwater, propulsion to allow a 7 knot cruise speed, side scan sonar for bottom searches, compass, etc. Much of this hardware is unconventional and will require R & D input to perfect.

These are a few of the many developments being pursued in the underwater vehicle business. The list of developments is almost endless and will no doubt continue to be so as man persists to attempt to conquer the oceans.

C.U.T.C. TRAINING

By

Mr. J.A. Fortin
Canadian Underwater Training CentreINTRODUCTION

What can only be called explosive growth has marked the international field of professional diving in the last ten years. The requirement for Underwater workers in support of the offshore oil industry increases yearly. Divers are in demand in such areas as the North Sea, the Middle East, the South Pacific, South and Central America, Gulf of Mexico, United States' eastern coast, and now in Canada's high Arctic, and offshore Nova Scotia and Labrador. Increased coastal and Great Lakes construction is continually requiring technicians specialized in various underwater skills.

Before 1970, many commercial diving companies either depended on the supply of ex-navy salvage divers to fill their ranks, or trained them themselves. More recently, underwater training centres located in the United States, United Kingdom and Norway have been working towards this need and a few community colleges have also been offering programs.

A recent survey of the foreign schools has indicated that a large number of Canadians attend every year. It is as a result of this increased Canadian interest in commercial diver training, a rapidly increasing national and international demand, and the requirement for an exclusive underwater facility in Canada capable of specialized, up-to-date training that the Canadian Underwater Training Centre has been created. The C.U.T.C. is a privately funded school which represents a major joint effort between industry and professional educators. Its aims are to develop a centre dedicated exclusively to the training of the various underwater skills for Canadians. The founders of C.U.T.C. are employers and educators experienced in the development and operations of commercial diver training programmes.

The objective and standards are designed to offer to both French and English-speaking students, more specialized, intense, all-inclusive field-orientated programmes. Curricula have been carefully designed with training quality in mind. Emphasis is placed on rigid safety standards and applied expertise to develop not only competent divers, but also well-rounded marine-orientated workers. To ensure constant updating of the curricula, a technical advisory board of key industry leaders has been established.

The centre is located at the Toronto Harbour and offers training in state-of-the-art equipment and techniques. The facility, a unique self-contained ship of approximately 260 feet in length, includes classrooms, offices, barges, diving tanks, and underwater work areas. Offshore of Toronto, water depths are in excess of 50 metres for more advanced training, while various harbour and lake front underwater installations offer the students exposure to actual field conditions. Canadian Underwater Training Centre will meet existing and proposed national and international standards and government regulations.

The training of underwater technicians and workers has been carried out successfully in the United States and overseas for the past 10-15 years. Statistics indicate that graduate employment averages 80% in related jobs, and all indications are that this increasing demand will continue to exist.

The basic Air/Mixed Gas Course provides resident training to prepare the student for commercial diving and tending. It includes classes in design and operation of all major diving equipment and their functions in underwater operations. The graduate will be qualified in diving techniques, breathing both air and other gases, and their practical applications in marine construction, salvage, and offshore oil operations. Upon completion of Basic Training, various specialty courses are offered. These include: underwater photography, underwater video television systems, non-destructive testing, underwater wet welding, bell and saturation techniques and emergency medical technician duties.

THE FIRST STEP

Admission Requirements

The selection criteria in this programme have three purposes:

- (1) to select people to be competent underwater and topside workers as required in the commercial diving industry;
- (2) to minimize attrition during diving training;
- (3) to select people capable of developing a career in commercial diving.

Mandatory Requirements

1. Must pass an approved medical examination administered by a qualified physician. Verification of tetanus immunization is also required. Medical costs are the complete responsibility of the applicant.
2. Must be a competent swimmer.

3. Must pass a pressure tolerance test. (This is conducted during the first week of the course. There have been very few cases where a student cannot pass this test; however, if you have trouble equalizing pressure in your ears or sinuses while flying or swimming underwater, you are encouraged to obtain a pressure test prior to attending.)
4. Must possess a certificate of secondary school education or equivalent. An exemption may be made if the prospective student has the ability to benefit from the training offered. This is determined by a review of experience, background, an interview, and the results of the entrance tests.
5. Must have the desire and willingness to devote a great deal of effort towards successfully completing the course.
6. Must be between the ages of 18 and 40.
7. Must have either sport, military, or commercial underwater experience. (Applicants without previous diving experience must attend a prerequisite S.C.U.B.A. Training Programme prior to attending the regular classes).

Desirable Requirements

Should possess work experience or skills involving manual dexterity in fields such as mechanics, construction, seamanship or other trades. Applicants who have neither appropriate work or underwater experience are unlikely to be successful at C.U.T.C.

THE TRAINING SHIP

Facilities and Equipment

C.U.T.C.'s unique campus is located aboard a 260 ft. ship, The "M.V. FUEL MARKETER", moored in Toronto Harbour. The "FUEL MARKETER" is an "ex" Shell Tanker, which has been professionally converted into a commercial diver training centre. The cargo holds, which once contained oil, are now 20 ft. deep training tanks. One tank contains a lock-out trunk for access to the harbour bottom below, while others are used for various underwater projects. Other areas of the vessel contain classrooms, a double-lock hyperbaric chamber, photo labs, workshops, offices, locker rooms, library and student lounge areas. Offshore field training is conducted aboard C.U.T.C.'s 46 ft. tug, the "F.M. STING" and a 50 ft. long deep diving barge.

Equipment used at C.U.T.C. represents the latest in design and development available and is indicative of the types found in the industry today.

Training aboard an actual diving ship allows the student to learn by doing, under actual field conditions and disciplines. Local harbour structures, and developing offshore installations offer the trainee actual on-the-job conditions under which to develop his skills.

Club Tours

Tours of C.U.T.C. facilities are available through the Registrar's Office. Groups or clubs are encouraged and prior approval by C.U.T.C. is required.

Trainee Assessment and Standards of Achievement

A system of continuous assessment throughout the course is used to assess individual practical diving and underwater tasks. These become increasingly more difficult as the course progresses. It also provides a close monitoring of trainee progress towards achievement of the terminal objectives, hence enabling those trainees who are unlikely to be successful to be identified. For some theoretical subjects, written tests are used throughout the programme. These tests may be in the format of multiple choice, true or false, and completion of constructive answers, and may be either 'open' or 'closed' book. Trainee log books and oral tests also form an appropriate part of the assessment system.

The instructor will set out the standard of achievement for each of the assessment tasks, and show their relationship to the terminal objectives. Pass grades range from 70% competency to 100% competency, and are based on the importance of the objective to health, safety, and competency.

Students are also required to maintain a high level of self-discipline and responsibility. Habitual failure to comprehend orders, displays of temper, panic, unsafe conduct, or non-compliance with school regulations and objectives will be grounds for dismissal. A record of progress is maintained and is available to the student or authorized persons.

Grades

- "A" - 90 - 100% - excellent;
- "B" - 80 - 89% - good;
- "C" - 70 - 79% - satisfactory;
- "D" - 50 - 69% - failed
- "INC" - Incomplete

Graduation

The graduating student must have satisfactorily completed the academic course of study and developed the minimum level of skills required to enter the commercial diving field.

A certificate of completion is granted to the student who maintains a 70% grade average or better, and who completes all assignments and requirements satisfactorily. Students who have failed to maintain the required grades, but have completed the training will receive a letter of participation.

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