

# COMEX

## Hyperbaric Experimental Centre

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.... « **1965 - 2000** » ....

**36 years of deep diving  
and submarine techniques  
development**

*.... From helium to hydrogen ....  
and  
.... From -70 to -701msw ....*

\* \* \*

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## FOREWORD

### ***Back to the early times...***

When Henri G. DELAUZE founded COMEX in 1961, commercial diving was restricted to civil engineering operations at depths not exceeding 5 to 30 metres. Most of the diving was carried out by “one man and his dog” companies and only one large company had developed in France, SOGETRAM, because of its organisation and procedures, based on surface supplied diving equipment and Cousteau demand regulators.

At the time, the offshore oil industry was mainly operating in the Gulf of Mexico in shallow waters and employed hard hat divers. However, the oil companies were steadily drilling in the search of offshore fields and at around 1964-1965 they realised that beside few individuals, they could not rely on a pool of professional divers to support their field developments deeper than 50 metres.

Divers have used compressed air since the 19<sup>th</sup> century but air limits their depth of intervention to 30 metres, exceptionally to 50-60 metres, due to the narcotic potency of nitrogen and the density of the breathed gas that become serious physiological constraints.

The US Navy has used mixed gas diving with heliox mixtures (helium and oxygen) in the 30's and the Swedish Navy has tested hydrogen mixtures during the last world war. However, there were no scientific data on the physiological effects or decompression tables validated for men

Between 1965 and 1975, the industry had to invent it all and develop commercial diving: decompression tables, bounce dives and saturation dives, support vessel with dynamic positioning, etc. With determination and style, two companies set programmes to investigate deep diving with helium and launched the concept of saturation with deck chambers installed on board diving vessels. These were COMEX in France and OCEAN SYSTEMS in the USA.

As early as 1964, COMEX started the construction of its first Hyperbaric Experimental Centre or C.E.H. (Centre Expérimental Hyperbare) with a capacity of 365 metres (1,200 feet according to the oil industry culture that had not yet adopted the metric system...). In the following years, two important additional systems were added to the new site at Marseille:

- A 300 metres hyperbaric system dedicated to the development of underwater technologies based on the "HYDROSPHERE" (a large spherical chamber, 5 metres wide and of a volume of 70 m<sup>3</sup>) half filled with water to simulate an underwater worksite and connected to a saturation living chamber accommodating eight persons
- A modular saturation system for the physiological studies under helium that later was adapted to saturation diving with hydrogen to depths up to 800metres.

COMEX associated to these systems designed for men interventions, two diving simulators to run animal experiments. One system had the capacity to run "rats" and "mice dives" at 2000 metres, and another was designed to accommodate groups of up to four monkeys to a depth of 1200 metres during long duration saturation exposures under any type of gases, including hydrogen.

A team of COMEX people, directed by the founders Henri G. DELAUZE and Dr. Xavier FRUCTUS, was set up with doctors, engineers, scientific investigators along with deep divers and technicians, all selected from the pool of operational personnel working for COMEX around the world.

During 30 years, this COMEX team has brilliantly conducted more than 5300 operations including nearly 2700 human experimental dives, either scientifically or equipment oriented, and more than 400 animal experiments.

The series of scientific dives, the goal of which was to progressively reach deeper depths, has permitted to study the physiology of saturation diving with helium from 45 to 610 metres and with hydrogen from 70 to 701 metres. More than 400 different divers participated to these dives, some of which lasting several weeks. The longest, in 1989, lasted 74 days and was commissioned by the ESA (European Space Agency) and the CNES (Centre National d'Etudes Spatiales) for the first study of remote-medicine and confinement conditions of the HERMES / COLUMBUS European space programme

COMEX had been chosen by the ESA (European Space Agency) in 1988 for designing and operating at Marseille the European Space Centre for the education and the training of astronauts to EVA (extra vehicular activities) but its implementation was stopped by the cancellation of the HERMES / COLUMBUS programme by the ESA in the early 1990's.

With regard to the technical dives organised for the testing of the divers' equipment (hot water suits, gas rebreathers, diving helmets, etc.), manual and automatic welding operations or other underwater technologies, 800 saturation divers stayed in the HYDROSPHERE habitat at depths ranging from 15 to 300 metres.

The technical and medical teams of the COMEX Hyperbaric Experimental Centre also carried out a series of 2500 oxygen and narcosis tolerance tests for the selection of the company divers or external personnel along with some bounce screening dives with helium to 210 metres.

From 1965 to 2000, the technical and scientific programmes conducted by COMEX at the Marseille Hyperbaric Experimental Centre have represented an overall budget of 2 billions French Francs, that is approximately 60 millions French Francs per year.

On the equipment side, COMEX designed and constructed around 80 large saturation systems and experimental hyperbaric centres. Among them, fifty were built for the company needs and thirty were delivered to industrial companies or navies around the world. Five DSV (diving support vessel) and two semi-submersible platforms with DP (dynamic positioning) system were designed and launched by COMEX, among them the SEABEX, first diving support vessel with a DP system in the offshore industry launched in 1977. Previously, the company fleet included the SANDOKAN barge and the TALISMAN diving vessel that after completing their North Sea campaigns were sent to work in the oil fields in the Gulf of Mexico.

In addition to this, many civilian submarines were designed and built in the COMEX workshops: observation submarines, divers lock out submarines, military salvage submarines and tourist submarines such as the SEABUS, a submarine with an acrylic shell that provided a panoramic vision for its 50 passengers. The SAGA, a divers lock out submarine rated for 600 metres and powered by a Stirling engine, displacing 545 tons underwater, was constructed in collaboration with the IFREMER in the 80's and still remains the world largest divers lock out submarine.

## 1. INTRODUCTION

The missions of the CEH Hyperbaric Experimental Centre (Centre d'Essais Hyperbares) of COMEX have included from 1965 to 2000 two main objectives:

- *The study of the physiology and the biology related to the effects of the pressure and gasses on the living organisms during short and long duration exposures.*
- *The study of equipment and procedures allowing divers to work safely and efficiently on deep underwater worksite, either in bounce diving or in saturation diving.*

The research and development programmes associated to these objectives were conducted in parallel and at a sustained pace, in order to allow COMEX to anticipate the operational needs of the oil companies that were considering subsea production systems for the exploitation of progressively deeper offshore oil fields.

However, if the main function of the COMEX Hyperbaric Experimental Centre was to run hyperbaric studies, some normobaric and hypobaric studies have also been performed during the last fifteen years within the frame of medical research programmes.

The 5329 operations that have been carried out during 36 years at the COMEX Hyperbaric Experimental Centre can be classified into four groups:

- Experimental dives with a physiology oriented programme,
- Experimental dives a technical oriented programme
- Hyperbaric and hypobaric equipment test.
- Microbiology programmes

All these operations are summarised in table 1.

## 2. PHYSIOLOGY ORIENTED EXPERIMENTAL DIVES

The physiology oriented experimental dives were performed partly with animal models to study and quantify the effects of pressures and breathing gasses on the organism and partly with professional divers to validate the data on man and obtain the scientific data required for the development of human intervention techniques at depths.

Various breathing mixtures other than air were evaluated, and in particular:

- *NITROX (Nitrogen / Oxygen)*
- *TRIMIX (Helium / Nitrogen / Oxygen)*
- *HELIOX (Helium / Oxygen)*
- *HYDROX (Hydrogen / Oxygen)*
- *HYDRELIOX (Hydrogen / Helium / Oxygen)*

## 2.1. ANIMAL EXPERIMENT DIVES

The dives using the animal model have involved two types of animals:

- Small laboratory animals (mice, rats, rabbits) specifically raised for medical experiments.
- Large animal such as dogs and monkeys. When monkeys were used, they were generally trained to perform a given quantified task to be able to correlate their performances with the neuro-physiological measurements and the dive conditions. The animals were dispatched over groups of two or four, to account for the social links within the groups. Each group performed several experimental dives, as if they were commercial divers, and were taken as their own reference for the measurements. COMEX Hyperbaric Experimental Centre policy has always been to “bring them alive” and thus, after the dive, the animals were brought back healthy to their home, or to the zoo when time for retirement came.

### **- Mice and rats :**

Mice and rats were used for a series of biological, bacteriological and neuro-physiological studies under hyperbaric conditions using breathing mixtures such as air, nitrox, heliox, hydrox and hydreliox. They also were used as animal model for decompression studies with these various breathing mixtures. A total of 180 experiments were performed in the range of 70 to 2000 metres between 1970 and 1998.

### **- Rabbits :**

A total of 120 experiments from 25 to 150 metres were carried out with rabbits in between 1970 and 1982 that were mainly oriented towards pharmacology studies. Rabbits were also used for gas wash out experiments designed for decompression studies using air and heliox mixtures.

### **- Dogs :**

A series of 33 experiments was conducted between 1974 and 1975 using dogs for haematology studies after the decompression of dives to 60 metres on air.

### **- Monkeys :**

Baboon monkeys named “Papio-Papio” were mainly used for the study of the High Pressure Nervous Syndrome (HPNS) and were prepared for electro-encephalography measurements. Neuro-biology experiments were also carried out with ‘fascicularis’ monkeys equipped with an electro-polarographic intracerebral probe for the study of the dopaminergic activity during the preparation phase of the HYDRA 10 experiment. The maximum depth reached was 1200 metres with Hydreliox, 1000 metres with Hydrox and 800 metres with Heliox breathing mixtures.

Between 1967 and 1991, a total of 86 long duration experiments was performed in hyperbaric chambers, the longest one reaching 50 days for a group of four monkeys at the depth of 380 metres.

## 2.2. HUMAN EXPERIMENT DIVES

Two diving techniques have been used during the manned experimental dives (around 2700):

- The bounce diving technique that consists in a bottom phase immediately followed by decompression to the surface.
- The saturation diving technique during which the divers are stored under pressure and live in a chamber located on the surface support (vessel, barge, platform, etc.). Every day, the divers are transferred under pressure on the work location at the bottom using a diving bell. The final decompression to the atmospheric pressure only takes place at the end of the work phase or at the end of the authorised saturation time which varies from two to four weeks depending on regulations.

### - Bounce dives :

The development of bounce diving has covered two types of tests.

- 2122 divers screening tests in chamber at depth between 6 and 100 metres with air and oxygen as breathing mixtures for the study of susceptibility to narcosis and oxygen toxicity during the selection of professional divers. Studies were also conducted for the screening of athletes from various sport activities under hyperbaric oxygen.
- 258 men dives for the validation of decompression models and the testing of decompression tables to depths up to 210 metres, using heliox breathing mixtures.

The first deep bounce dive in an onshore chamber started on December 1966 in the new Hyperbaric Experimental Centre that COMEX has just finished building. Christian Boy and Guy Deloraine were pressurised at 150 metres in a chamber and initiated a long series of experimental dives. A second deep bounce dive was planned offshore the following year, in 1967, using the first diving bell constructed by COMEX and called IDEFIX, in which C Boy and J Dupré did an open sea dive to 150 metres.

### - Saturation dives :

The programmes of human experimental saturation dives are classified into nine groups:

- |                            |                         |
|----------------------------|-------------------------|
| • <i>LUDION</i>            | • <i>SAGITTAIRE</i>     |
| • <i>PLC<sup>(*)</sup></i> | • <i>CORAZ</i>          |
| • <i>PHYSALIE</i>          | • <i>HYDRA</i>          |
| • <i>JANUS</i>             | • <i>HYDRA - LUDION</i> |
| • <i>BELUGA</i>            |                         |

(\*) also called "Plongée au Long Cours"



- « **LUDION** » dives (1967 - 1970) :

Three operations in the range of 100 metres, using Trimix and Heliox mixtures took place:

- **Ludion 1** :       - Depth        : 45 / 100 metres  
                  (1967)       - Divers        : P. Blenet - P. Couture - H. Raibaldi
- **Ludion 2** :       - Depth        : 85 / 120 metres  
                  (1967)       - Divers        : J.C. Descamps - C. Wesly
- **Ludion 3**       - Depth        : 75 / 102 metres  
                  (1970)       - Divers        : G. Mirey - B. Reuiller

- « **PLC** » Dives (1968) :

Three operations in the range of 300 metres using Trimix breathing mixtures were performed to study the effects of pressure on man:

- **PLC 1**           - Depth        : 335 metres  
                      - Divers        : A. Jullien - R. Veyrunes
- **PLC 2**           - Depth        : 266 metres  
                      - Divers        : J. Dupré - H. Raibaldi
- **PLC 3**           - Depth        : 300 metres  
                      - Divers        : P. Fructus - A. Jullien

- « **PHYSALIE** » dives(1968 - 1972) :

Six operations between 300 and 610 metres using Trimix and Heliox breathing mixtures were performed to study the physiology and the medical aspects of man at depths never reached at the time.

It was during the PHYSALIE 1 experiment at 335 metres using Heliox breathing mixture that the High Pressure Nervous Syndrome (HPNS) was first identified and described in man.

- **Physalie 1**       - Depth        : 335 metres  
                  (1968)       - Divers        : R.W. Brauer - H.G. Delauze
- **Physalie 2**       - Depth        : 360 metres  
                  (1968)       - Divers        : R.W. Brauer - R. Veyrunes
- **Physalie 3**       - Depth        : 365 metres  
                  (1968)       - Divers        : R.W. Brauer - R. Veyrunes
- **Physalie 4**       - Depth        : 300 metres  
                  (1968)       - Divers        : J. Dupré - F. Fallourd
- **Physalie 5**       - Depth        : 520 metres  
                  (1970)       - Divers        : P. Chemin - B. Reuiller
- **Physalie 6**       - Depth        : 610 metres  
                  (1972)       - Divers        : P. Chemin - R. Gauret

- « **SAGITTAIRE** » dives (1971 - 1974) :

Four operations between 300 and 610 metres using Heliox breathing mixture conducted for the study of the behaviour and physical and intellectual performances of divers during deep saturation dives of long duration.

- **Sagittaire 1** - Depth : 300 metres  
(1971) - Divers : B. Adam - B. Brousse - P. Léonard  
F. Sicardi
- **Sagittaire 2** - Depth : 500 metres  
(1972) - Divers : F. Huteau - J. Thollas
- **Sagittaire 3** - Depth : 300 metres  
(1973) - Divers : G. Dignand - F. Foucher - R. Gauret  
C. Prefaut
- **Sagittaire 4** - Depth : 610 metres  
(1974) - divers : C. Bourdier - A. Jourde

- « **JANUS** » dives (1968 - 1977) :

Ten operations (including three at sea) between 150 and 501 metres using Heliox and Trimix breathing mixtures designed to demonstrate the operational capacity of divers at great depths in a full scale job. Some of these dives were conducted in association with the French Navy.

- **Janus 1 - Phase 1** - Depth : 100 / 150 metres  
(1968) - Divers : J. Monjoin - Nys
- **Janus 1 - Phase 2** - Depth : 100 / 150 metres (**at sea**)  
(1968) (Phase 2A) - Divers : F. Poutet - D. Renard  
(Phase 2B) - Divers : J. Monjoin - Ponneau
- **Janus 2 - Phase 1** - Depth : 200 / 250 metres  
(1970) - Divers : J. Monjoin - P. Cadiou  
C. Cornillaux - M. Liogier
- **Janus 2 - Phase 2A** - Depth : 200 / 250 metres  
(1970) - Divers : P. Cadiou - C. Cornillaux  
M. Liogier
- **Janus 2 - Phase 2B** - Depth : 200 / 250 metres  
(1970) - Divers : P. Chemin - G. Mirey  
B. Reuiller
- **Janus 2 - Phase 3** - Depth : 200 / 250 metres (**at sea**)  
(1970) - Divers : P. Cadiou - C. Cornillaux  
M. Liogier
- **Janus 3 - Phase A** - Depth : 390 / 415 metres  
(1974) - Divers : R. Roul - G. Straub - P. Valéani

- **Janus 3 - Phase B** (1974) - Depth : 395 / 415 metres -:  
- Divers : C. Guichard - C. Samanos  
M. Quéchon
- **Janus 4 - Phase A** (1976) - Depth : 400 / 445 / 460 / 480 metres  
- Divers : P. Jeantot - J. Mc Kenna  
D. Lentini - P. Raude  
L. Schneider - E. Sevellec  
J. Verpeaux - G. Vial
- **Janus 4 - Phase B** (1977) - Depth : 430 / 460 / 501 metres (**at sea**)  
- Divers : P. Jeantot - P. Raude  
L. Schneider - E. Sevellec  
J. Verpeaux - G. Vial

- **BELUGA dives (1970 - 1973):**

Fives operations between 120 and 200 metres using Heliox breathing mixture designed to study divers at work in cold waters(- 2°C).

- **Béluga 1** (1970) - Depth : 158 / 200 metres  
- Divers : P. Chemin - B. Reuiller - L. Sanchez
- **Béluga 2** (1971) - Depth : 120 metres  
- Divers : P. Chemin - B. Reuiller - Logan  
Manzo - P. Mura
- **Béluga 3** (1971) - Depth : 120 / 180 metres  
- Divers : Geraud - F. Huteau - M. Liogier  
Porter - Toccia
- **Béluga 4** (1971) - Depth : 120 / 180 metres  
- Divers : F. Huteau - P. Chemin - P. Léonard  
P. Mura
- **Béluga 5** (1973) - Depth : 60 metres  
- Diver: Dubail - J. Crozier

- **CORAZ dives (1975) :**

Four operations at 300 metres using Trimix and Heliox breathing mixtures designed for the study of rapid compressions.

- **Coraz 1** - Depth : 300 metres  
- Divers : C. Bourdier - A. Jourde  
P. Rosengren
- **Coraz 2** - Depth : 300 metres  
- Divers : C. Bourdier - A. Jourde
- **Coraz 3** - Depth : 300 metres  
- Divers : M. Ganglof - R. Gauret
- **Coraz 4** - Depth : 300 metres  
- Divers : J. Griselin - J.P. Mary

- **HYDRA dives (1968 - 1996) :**

Series of deep experimental dives conducted for the development of hydrogen breathing using Hydrox and Hydreliox mixtures.

Fourteen operations between 70 and 701 metres including five in open sea conditions. Two world records were set, the first one in onshore conditions at 701 metres with simulated work in water at 660 metres and the second one at sea at 520 and 534 metres with the actual connection of a riser pipe using bolted flanges (performed in co-operation with the French Navy).

Note: The COMEX Hyperbaric Experimental Centre is the only experimental centre in the world with the capacity of running manned saturation dives using hydrogen mixtures.

- **Hydra 1 (1968)** - Depth : 255 metres (**at sea**)  
- Divers : J. Dupré - F. Fallourd - R Veyrunes
- **Hydra 2 (1969-1970)** *Eight animal dives (Monkeys) using Hydrox*  
- depth : 150 / 200 / 300 / 500 / 700 metres
- **Hydra 3 A (1983)** *Bounces dives at sea using Heliox with a switch to Hydrox at bottom.*  
- Depth : 70 metres  
- Divers : M. Avon - C. Boy - J. Burnier  
A. Burseaux - G. Ceze - B. Gardette  
Y. Giran - M. Giraud - G. Guerrier  
P. Lediuzet - J. Mambré  
A. Murracioli - M. Plutarque  
B. Richardson - T. Ruysen - A. Tocco
- **Hydra 3 B (1983)** - Depth : 90 metres (*Bounce dive at sea*)  
- Divers : J.P. Bargiarelli - H.G. Delauze
- **Hydra 4 (1983)** - Depth : 180 / 210 / 240 / 300 metres  
- Divers : M. Cross - M. Giraud - G. Guerrier  
J. Le Mire - J. Norman - L. Schneider
- **Hydra 5 (1985)** - Depth : 450 metres  
- Divers : S. Icart - Y. Langouet - P. Macchi  
J.G. Marcel Auda - P. Raude  
L. Schneider
- **Hydra 6 (1985)** - Depth : 500 / 520 metres  
- Divers : Th. Arnold - J.P. Bory - M. Diaz  
P. Gaide - S. Icart - P. Raude  
L. Schneider - P. Vergier
- **Hydra 7 (1986)** - Depth : 260 metres  
- Divers : P. Choirat - A. de Nechaud de Féral  
J. Henrion - R. Peilho
- **Hydra 8 (1988)** - Depth : 500 / 520 / **534 metres**  
(**Operation at sea - world record**)  
- Divers : Th. Arnold - S. Icart - J.G. Marcel Auda  
R. Peilho - P. Raude - L. Schneider

- **Hydra 9 (1989)**
  - Depth : 120 / 150 / 180 / 210 / 240 / 270 and 300 metres (**duration: 74 days**)
  - Divers : B. Bourrousse - P. Choirat  
G. Laurent - A. de Nechaud de Féral  
R. Peilho - L. Schneider
- **Hydra 10 (1992)**
  - Depth : 675 / **701 metres (world record)**
  - Divers : S. Icart - **Th. Mavrostomos**  
R. Peilho
- **Hydra 11 (1994)**
  - Depth : 335 / 350 / 365 metres
  - Divers : J. Baert - H. Cloarec - Y. Davalan  
D. Lemaitre
- **Hydra 12 - Phase A (1996)**
  - Depth : 120 metres
  - Divers : J. Baert / J.C. Bret
- **Hydra 12 - Phase B (1996)**
  - Depth : 200 / 210 metres (**at sea**)  
( « Helium IN - Hydrogen OUT » Technique)
  - Divers : J. Baert - J.C. Bret  
H. Cloarec - D. Lemaitre

- **HYDRA - LUDION dives (1998 - 1999) :**

The objective of these two operations was to study the feasibility of excursion dives of high amplitude using hydrogen during the excursion and helium at the saturation depth at 100 and 300 metres. The goal was also to study hydrogen decompression rates faster than the one used for helium saturation.

- **Hydra - Ludion 1 (1998)**
  - Depth : 200 / 230 / 245 / 260 / 290 et 300 metres
  - divers : F. Begue - R. Milesi
- **Hydra - Ludion 2 (1999)**
  - Depth : 100 / 130 / 140 / 150 / 160 / 200 / 260 / 275 and 290 metres
  - Divers : E. Leteurtois - W. Lopes  
R. Milesi - Th. Mavrostomos  
C. Planchat

In parallel to these experiments, a significant number of saturation dives has been conducted for the validation of decompression tables and the selection of divers for deep operations. Dives were also performed for the training of personnel from clients for which COMEX had designed and constructed deep diving equipment (deep divers lock out submarines, submarine escape procedures, saturation systems and bells, hyperbaric test centres, etc.). Table 2 summarises the history of these operations.

During these various research and development programmes, the COMEX Hyperbaric Experimental Centre was automated to increase its efficiency and safety. This increasing computer control associated to a highly qualified personnel, has permitted a significant reduction of the running costs and the continuing activity of the centre, while at the same time, the other hyperbaric centres progressively reduced their activity during the 90's and in certain cases, completely stopped operating.

### **- « Therapeutic » treatments :**

For many years, the COMEX Hyperbaric Experimental Centre has been one of the rare installations in France with the capacity of treating persons who had been intoxicated by carbon monoxide or recreational divers with symptoms of decompression sickness.

At the end of the 60's, COMEX initiated the industrial development of hospital hyperbaric chamber to be used for Oxygen Hyperbaric Breathing (OHB) treatments that have since been progressively recognised worldwide.

### **« Hypobaric » experiments :**

The chambers at the COMEX Hyperbaric Experimental Centre were designed both for hyperbaric and hypobaric conditions. A series of low pressure manned exposures were done for medical, physiological and biological projects related to the high altitude syndrome (mining at altitude, parachuting, pilots, mountaineering, etc.).

The operation called « EVEREST-COMEX 97 » (Everest III) was a simulated exposure at altitude conducted at the COMEX Hyperbaric Experimental Centre which was modified to permit eight men to live safely at a pressure equivalent to the summit of Mount Everest (8848 metres). A 36-days exposure allowed studying the effect of acute hypoxia in man associated to very high mountain altitude.

## **3. TECHNICAL EXPERIMENTAL DIVES**

In addition to these scientific projects, the COMEX Hyperbaric Experimental Centre has conducted an important number of men dives during which the techniques of hyperbaric manual stick welding and MIG, MAG or TIG torch welding were developed. Later, an automatic welding machine named THOR (TIG Hyperbaric Orbital Robot) was developed and tested. The use of welding robots has since been extended to the welding of all oil and gas subsea pipelines. For these welding operations performed inside a welding habitat, systems of gas scrubbing and atmosphere regeneration had to be validated by toxicology and medicine studies. The technical experimental dives are summarised in table 3.

## **4. MICROBIOLOGY EXPERIMENTS**

The expertise gained with the control of confined atmosphere in chambers, using various types of gases and in particular hydrogen, has permitted the COMEX Hyperbaric Experimental Centre to become the partner of medical and biomedical research laboratories, specialised in the cell micro-biology. This expertise was used for the production of artificial tissues or studies of parasitic diseases and cell cancer generating oxygen free radicals. For these projects, the COMEX Hyperbaric Experimental Centre was equipped with automatic incubators that were used for cell culture under hypobaric, normobaric and hyperbaric conditions using all type of gases, including hydrogen.

## 5. TESTS EQUIPEMENTS

In addition to the above physiology experimental operations, the COMEX Hyperbaric Experimental Centre has proceeded with more than 2000 equipment tests under hydrostatic conditions and dynamic monitoring to pressures up to 400 bar (pressure equivalent to a depth of 4000 metres).

## 6. THE SCIENTIFIC AND TECHNICAL STRUCTURES

The scientific and technical teams of the COMEX Hyperbaric Experimental Centre have benefited for long of a world-wide fame.

- **Scientific team** : *C. Agaraté - M. Carlioz - Dr M. Comet - Dr V. Conti  
H.G. Delauze - J.C. Dumas - J. Dupré - Dr P. Fructus  
Dr X. Fructus - B. Gardette - Dr Y. Giran - C. Gortan  
P.Gouret - J. Griselin - J.P. Imbert - C. Lemaire  
Dr J. Le Mire - Dr J.Y. Massimelli - Dr R. Sciarli  
Dr F. Sicardi*
- **Technical team** : *J.P. Bargiarelli - A. Bened - V. Bianco - J. Corbier  
J. Coustal - H.G. Delauze - F. Dupré - J. Dupré  
C. Gortan - A. Martin - P. Martin - A. Payraud  
D. Prospéri - A. Tocco*
- **Ethical committee** :  
- *Dr B. Broussolle*  
- *Dr P. Giry*  
- *Pr Y. Jammes*  
- *Dr J.L. Meliet*  
- *Dr R. Naquet*  
- *Pr P. Vanuxem*
- **Scientific Co-operations** :  
- *CNRS (GIS physiologie hyperbare - Dr J.C. Rostain)*  
- *INSERM*  
- *Facultés des Sciences*  
- *Facultés de Médecine*  
- *Facultés de Pharmacie*  
- *CNEXO / IFREMER*  
- *CERB / IMNSSA (French Army)*  
- *GERS / GISMER / CEPISMER (French Navy)*  
- *INPP (Institut National de Plongée Professionnelle)*  
- *CNES (Centre National d'Etudes Spatiales)*  
- *ESA (European Space Agency)*  
- *NMRI (Naval Medical Research Institut - U.S. Navy)*  
- *SINTEF (Norway)*

## 7. R&D BUDGETS from 1965 to 2000

The overall budget that COMEX has devoted to the R&D programmes for the techniques of underwater interventions reaches **310 Millions Euros** and is split along the following items:

- R&D in « **Hyperbaric Physiology** » from 1965 to 2000 :
  - **148 Millions Euros**  
Which corresponds over the last 36 years to an average of 4,11M€ / year  
The part related to the development of hydrogen diving reaches 30,5 M€
- R&D in « **Hyperbaric Technologies** » from 1968 to 2000 :
  - **162 Millions Euros**  
Which corresponds over the last 33 years to an average 4.9 M€ / year

The overall budget of 310 Millions Euros represents over the last 36 years an average annual R&D investment of 8,6 Millions Euros per year.

COMEX has received for these research and development programmes financial supports in the form of subventions or reimbursable loans to an average of 25% of the project cost from the following public agencies:

- *Ministère de l'Industrie (DHYCA - DIMAH)*
- *Ministère de la Défense (DRET - DGA)*
- *Secrétariat d'Etat à la Mer (CNEXO)*
- *European Commission (EC) :*
  - *Directorate General of Research (DG XII)*
  - *Directorate General of Energy (DG XVII)*
- *Conseil Régional PACA*
- *Conseil Général 13*



Table 1

Summary of all operations (all types) conducted at  
the COMEX Hyperbaric Experimental Centre from 1965 to 2000

Nature of operations	Years	Number of operations	Depth metres	Number of subjects	Number of days/chamber	Number of subj. / days
<b><u>MICROBIOLOGICAL EXPERIMENTS</u></b>						
Keratinocytes / Huvec cancer cells, Bacterias	1994 - 1999	155	70 to 2000	NA	310	NA
<b>Total</b> <i>means on 6 years</i>		<b>155</b> <i>26 ope./year</i>			<b>310</b> <i>52 d/ch/year</i>	
<b><u>ANIMAL DIVES</u></b>						
Mice / Rats	1970 - 1998	180	70 to 2000	1500	900	7500
Rabbits	1970 - 1982	120	25 to 150	480	120	480
Dogs	1974 - 1975	33	60	33	33	33
Monkeys	1967 - 1991	86	30 to 1200	181	986	2162
<b>Total</b> <i>means on 32 years</i>		<b>419</b> <i>13 ope./year</i>		<b>2194</b> <i>69 anim/year</i>	<b>2039</b> <i>64 d/ch/year</i>	<b>10175</b> <i>318 an/d/year</i>
<b><u>HUMAN DIVES</u></b>						
<b>Physio. "bounce dives" :</b>						
O2 and N2 toxicity tests	1965 - 2000	2122	6 to 100	5350	2104	5350
Decompression tests	1965 - 1985	258	20 to 210	516	387	774
Therapeutic treatments	1965 - 1980	70	12 to 50	98	70	98
<b>Total "bounce dives"</b> <i>means on 36 years</i>		<b>2450</b> <i>68 ope./year</i>		<b>5964</b> <i>166 men/year</i>	<b>2561</b> <i>72 d/ch/year</i>	<b>6222</b> <i>173 men/d/year</i>
Physio. "saturation dives" (see table 2)	1967 - 1999	100	15 to 701	403	1095	4571
Techno. "saturation dives" (see table 3)	1973 - 1992	125	12 to 300	795	1006	7110
<b>Total "saturation dives"</b> <i>means on 33 years</i>		<b>225</b> <i>7 ope/year</i>		<b>1198</b> <i>37 men/year</i>	<b>2101</b> <i>64 d/ch/year</i>	<b>11681</b> <i>354 men/d/year</i>
<b>Total "men dives"</b> <i>means on 36 years</i>		<b>2675</b> <i>75 ope/year</i>		<b>7162</b> <i>199 men/year</i>	<b>4662</b> <i>130 d/ch/year</i>	<b>17903</b> <i>498 men/d/year</i>
<b><u>EQUIPMENT TESTS</u></b>						
Hydrostatic tests	1965 - 2000	2080	-1 to 400 bar	NA	3240	NA
<b>Total</b> <i>means on 36 years</i>		<b>2080</b> <i>58 ope/year</i>			<b>3240</b> <i>90 d/ch/year</i>	
<b>Total (1965 to 2000)</b> <i>means on 36 years</i>		<b>5329</b> <i>operations</i>		<b>9356</b> <i>subjects</i>	<b>10251</b> <i>day/chamber</i>	<b>28078</b> <i>subject/day</i>
		<b>148/year</b>		<b>260/year</b>	<b>285/year</b>	<b>780/year</b>

**Table 2**

History of deep physiology experimental dives  
conducted by the COMEX Hyperbaric Experimental Centre using saturation diving  
(1967 - 1974)

Year	Date	Name of operation	Nature of gas	Depth metres	Duration days	Number of divers	Number men / day	Total operations
1967	16 to 21/05	LUDION 1	Trimix	45/100	6	3	18	1
	15 to 24/11	LUDION 2	Heliox	85/120	9	2	18	2
	<b>Total 1967</b>				<b>15</b>	<b>5</b>	<b>36</b>	<b>2</b>
1968	05 to 09/03	PLC 1	Trimix	335	5	2	10	1
	03 to 07/05	PLC 2	Trimix	266	5	2	10	2
	14 to 19/05	PLC 3	Trimix	300	5	2	10	3
	21 to 25/05	PHYSALIE 1	Trimix	335	5	2	10	4
	11 to 16/06	PHYSALIE 2	Héliox	360	6	2	12	5
	27/06 to 03/07	PHYSALIE 3	Trimix	365	7	2	14	7
	24 to 29/08	JANUS 1 - Ph.1	Héliox	90/150	6	2	12	8
	24 to 29/09	PHYSALIE 4	Trimix	300	6	2	12	9
	01 to 10/10	JANUS 1-Ph.2A (sea)	Heliox	100/150	10	2	20	10
	11 to 22/10	JANUS 1-Ph.2B (sea)	Heliox	100/150	12	2	24	11
	23/10 to 01/11	HYDRA 1	Hydrox	255	10	3	30	12
<b>Total 1968</b>				<b>77</b>	<b>23</b>	<b>164</b>	<b>12</b>	
1970	15/04 to 06/05	JANUS 2 - Ph.1	Heliox	200/250	21	4	84	1
	08 to 13/06	LUDION 3	Heliox	75/102	6	2	12	2
	04 to 20/08	JANUS 2 - Ph.2 A	Heliox	200/253	15	3	45	3
	25/08 to 10/09	JANUS 2 - Ph.2 B	Heliox	200/250	16	3	48	4
	16 to 28/09	JANUS 2 - Ph.3 (sea)	Heliox	200/250	13	3	39	5
	12 to 28/11	PHYSALIE 5	Heliox	520	16	2	32	6
	09 to 18/12	BELUGA 1	Heliox	158/200	10	3	30	7
	<b>Total 1970</b>				<b>97</b>	<b>20</b>	<b>290</b>	<b>7</b>
1971	14 to 19/05	BELUGA 2	Heliox	120	6	5	30	1
	23 to 29/05	BELUGA 3	Heliox	120/180	7	5	35	2
	01 to 06/06	BELUGA 4	Heliox	120/180	6	4	24	3
	04/11 to 03/12	SAGITTAIRE 1	Heliox	300	28	4	112	4
<b>Total 1971</b>				<b>47</b>	<b>18</b>	<b>201</b>	<b>4</b>	
1972	07/02 to 06/03	SAGITTAIRE 2	Heliox	500	20	2	40	1
	12 to 22/04	'SWECOM'	Heliox	300	11	4	44	2
	08/05 to 02/06	PHYSALIE 6	Heliox	610	23	2	46	3
<b>Total 1972</b>				<b>54</b>	<b>8</b>	<b>130</b>	<b>3</b>	
1973	26/02 to 03/03	SAGITTAIRE 3	Heliox	300	33	4	132	1
	25 to 30/06	BELUGA 5	Heliox	60	6	2	12	2
<b>Total 1973</b>				<b>39</b>	<b>6</b>	<b>144</b>	<b>2</b>	
1974	10/04 to 03/05	JANUS 3 - Ph. A	Heliox	390/415	20	3	60	1
	12/06 to 09/07	SAGITTAIRE 4	Heliox	610	28	2	56	2
	2 to 22/12	JANUS 3 - Ph. B	Heliox	395/415	20	3	60	3
<b>Total 1974</b>				<b>68</b>	<b>8</b>	<b>176</b>	<b>3</b>	

(continued on page 19)

**Table 2 (continued 1)**

History of deep physiology experimental dives  
conducted by the COMEX Hyperbaric Experimental Centre using saturation diving  
(1975 - 1979)

Year	Date	Name of operation	Nature of gas	Depth metres	Duration days	Number of divers	Number men / day	Total operations
1975	24/01 to 02/02	CORAZ 1	Trimix	300	10	3	30	1
	17 to 27/03	CORAZ 2	Trimix	300	11	2	22	2
	10 to 18/06	CORAZ 3	Trimix	300	9	2	18	3
	09 au 20/12	CORAZ 4	Heliox	300	12	2	24	4
<b>Total 1975</b>					<b>42</b>	<b>9</b>	<b>94</b>	<b>4</b>
1976	03 to 22/12	JANUS 4 - Ph. A	Trimix	400/480	19	8	152	1
	<b>Total 1976</b>					<b>19</b>	<b>8</b>	<b>152</b>
1977	15 to 29/10	JANUS IV-Ph. 3 (at sea)	Trimix	430/460/501	16	6	96	1
	30/03 to 02/04	Decompression tests	Heliox	120	4	2	8	2
	05 to 08/04	Decompression tests	Heliox	120	4	2	8	3
	23 to 26/05	Decompression tests	Heliox	120	4	2	8	4
	31/05 to 03/06	Decompression tests	Heliox	120	4	2	8	5
	14 to 16/06	Decompression tests	Heliox	35	3	2	6	6
	26 to 28/09	Decompression tests	Heliox	35	3	2	6	7
	04 to 08/10	Training Russians	Heliox	200	5	8	40	8
	17 to 23/10	Training Argentinians	Heliox	200	7	8	56	9
	24 to 30/10	Training Argentinians	Heliox	200	7	8	56	10
	15 to 17/11	Decompression tests	Air	35	3	2	6	11
	21 to 26/11	Decompression tests	Heliox	180	6	2	12	12
	28/11 to 03/12	Decompression tests	Air	27	6	2	12	13
	05 to 09/12	Decompression tests	Heliox	180	5	2	10	14
<b>Total 1977</b>					<b>77</b>	<b>50</b>	<b>332</b>	<b>14</b>
1978	04 to 09/01	Decompression tests	Heliox	180	6	2	12	1
	16 to 23/01	Decompression tests	Heliox	170/180	8	2	16	2
	24 to 28/01	Decompression tests	Nitrox	50	5	2	10	3
	30/01 to 05/02	Decompression tests	Air	50	7	2	14	4
	06 to 11/02	Decompression tests	Air	30	6	2	12	5
	20 to 27/02	Decompression tests	Heliox	180	8	2	16	6
	28/02 to 07/03	Decompression tests	Heliox	180	8	2	16	7
	14 to 18/03	Decompression tests	Heliox	100	5	2	10	8
	28/03 to 04/04	Decompression tests	Heliox	130/140	8	2	16	9
	20 to 22/11	Selection divers	Heliox	180	3	2	6	10
	29/11 to 01/12	Selection divers	Heliox	180	3	2	6	11
	04 to 10/12	Training Rumanians	Heliox	200	7	8	56	12
	06 to 08/12	Selection divers	Heliox	180	3	2	6	13
	<b>Total 1978</b>					<b>77</b>	<b>32</b>	<b>196</b>
1979	06 to 08/02	Selection divers	Heliox	180	3	2	6	1
	28/03 to 14/04	Cx/Gismer 79/131	Trimix	450	18	8	144	2
<b>Total 1979</b>					<b>21</b>	<b>10</b>	<b>150</b>	<b>2</b>

(Continued on page 20)

**Table 2 (continued 2)**

History of deep physiology experimental dives  
conducted by the COMEX Hyperbaric Experimental Centre using saturation diving  
(1980 - 1987)

Year	Date	Name of operation	Nature of gas	Depth metres	Duration days	Number of divers	Number men / day	Total operations
1980	24/03 to 30/03	Training Chinesees	Heliox	200	7	8	56	1
	30/03 to 05/04	Training Chinesees	Heliox	200	7	8	56	2
	02 to 06/06	Saturation air	Air	15	5	6	30	3
	07 to 13/07	Training Chinesees	Heliox	200	7	8	56	4
	15 to 21/07	Training Chinesees	Heliox	200	7	8	56	5
	28 to 30/10	Selection divers	Heliox	180	3	2	6	6
	25 to 28/11	Selection divers	Heliox	180	3	2	6	7
<b>Total 1980</b>					<b>39</b>	<b>42</b>	<b>266</b>	<b>7</b>
1981	05 to 08/03	Training Cetravim	Heliox	65	4	8	32	1
	09 to 12/03	Training Cetravim	Heliox	65	4	8	32	2
	15 to 18/07	Training Cetravim	Heliox	65	4	8	32	3
	15 to 18/12	Training Cetravim	Heliox	65	4	8	32	4
<b>Total 1981</b>					<b>16</b>	<b>32</b>	<b>128</b>	<b>4</b>
1982	13 to 15/04	Training Cetravim	Heliox	65	3	8	24	1
	23 to 30/04	NEREIDES	Air	15/75	8	8	64	2
	05 to 09/07	Training Cetravim	Heliox	65	4	8	32	3
	20 to 22/10	Training Cetravim	Heliox	65	3	8	24	4
	28/12 to 31/12	Training Chinesees	Heliox	65	4	8	32	5
<b>Total 1982</b>					<b>22</b>	<b>40</b>	<b>176</b>	<b>5</b>
1983	08 to 10/02	Training Cetravim	Heliox	65	3	8	24	1
	30/05 to 02/06	Training INPP	Heliox	65	4	8	32	2
	14/11 to 02/12	HYDRA 4	Hydrox / Hydreliox	300	19	6	114	3
<b>Total 1983</b>					<b>26</b>	<b>22</b>	<b>170</b>	<b>3</b>
1984	20 to 23/03	Training INPP	Heliox	65	4	8	32	1
<b>Total 1983</b>					<b>4</b>	<b>8</b>	<b>32</b>	<b>1</b>
1985	03/05 to 08/06	HYDRA 5	Hydreliox	450	36	6	216	1
<b>Total 1985</b>					<b>36</b>	<b>6</b>	<b>216</b>	<b>1</b>
1986	21/11 to 18/12	HYDRA 6	Hydreliox	500/520	28	8	224	1
<b>Total 1986</b>					<b>28</b>	<b>8</b>	<b>224</b>	<b>1</b>
1987	05 to 20/01	HYDRA 7	Hydrox	260	16	4	64	1
	06 to 10/10	JASON 1	Argox	15	5	4	20	2
<b>Total 1987</b>					<b>21</b>	<b>8</b>	<b>84</b>	<b>2</b>

(Continued on page 21)

**Table 2 (continued 3)**

History of deep physiology experimental dives  
conducted by the COMEX Hyperbaric Experimental Centre using saturation diving  
(1988 - 1999)

Year	Date	Name of operation	Nature of gas	Depth metres	Duration days	Number of divers	Number men / day	Total operations
1988	22/02 to 22/03	HYDRA 8 (at sea)	Hydreliox	534	29	6	174	1
				<b>Total 1988</b>	<b>29</b>	<b>6</b>	<b>174</b>	<b>1</b>
1989	09/10 to 21/12	HYDRA 9	Hydrox	300	74	4+2	296	1
				<b>Total 1989</b>	<b>74</b>	<b>6</b>	<b>296</b>	<b>1</b>
1992	02/11 to 14/12	HYDRA 10	Hydreliox	701	43	3	129	1
				<b>Total 1992</b>	<b>43</b>	<b>3</b>	<b>129</b>	<b>1</b>
1994	10/01 to 04/02	HYDRA 11	Heliox / Hydreliox	335/350/365	26	4	104	1
				<b>Total 1994</b>	<b>26</b>	<b>4</b>	<b>104</b>	<b>1</b>
1996	31/05 to 06/06  16 to 28/06	HYDRA 12 - Ph. A  HYDRA 12 - Ph. B (at sea)	Heliox / Hydrox  Heliox / Hydreliox	120	7	2	14	1
				200/210	13	4	52	2
				<b>Total 1996</b>	<b>20</b>	<b>6</b>	<b>66</b>	<b>2</b>
1997	01/04 to 06/05	EVEREST-COMEX 97 (EVEREST III)	Air	Alt. 8848m	36	8	288	1
				<b>Total 1997</b>	<b>36</b>	<b>8</b>	<b>288</b>	<b>1</b>
1998	04 to 22/12	HYDRA-LUDION 1	Heliox / Hydreliox	200/230/260	19	2	38	1
				290/300	<b>Total 1998</b>	<b>19</b>	<b>2</b>	<b>38</b>
1999	03 to 25/06	HYDRA-LUDION 2	Heliox / Hydreliox	100/130/160	23	5	115	1
				200/275/290	<b>Total 1999</b>	<b>23</b>	<b>5</b>	<b>115</b>
<b>Total (1967 à 1999)</b>					<b>1095</b>	<b>403</b>	<b>4571</b>	<b>100</b>
<i>means on 33 years</i>					<i>34 j/year</i>	<i>13 div./year</i>	<i>143 m/d/year</i>	<i>3 op./year</i>

**Table 3**

History of deep technology experimental dives  
Conducted by the COMEX Hyperbaric Experimental Centre using saturation diving  
(1973 - 1976)

Year	Date	Nature of gas	Depth metres	Duration days	Number of divers	Number men / day	Total operations
<b>1973</b>	16 to 29/10	Heliox	150	12	8	96	1
	<b>Total 1973</b>			<b>12</b>	<b>8</b>	<b>96</b>	<b>1</b>
<b>1974</b>	03 to 04/01	Heliox	120	2	4	8	1
	14 to 24/01	Heliox	150	11	8	88	2
	18 to 28/03	Heliox	150	11	8	88	3
	12 to 31/08	Heliox	24	20	8	160	4
	16 to 24/09	Heliox	150	9	8	72	5
	21 to 30/10	Heliox	150	10	8	80	6
	<b>Total 1974</b>			<b>63</b>	<b>44</b>	<b>496</b>	<b>6</b>
<b>1975</b>	08 to 17/01	Heliox	150	10	8	80	1
	24/02 to 02/03	Heliox	150	7	8	56	2
	10 to 19/04	Heliox	155	10	8	80	3
	11 to 22/05	Heliox	155	12	8	96	4
	01 to 07/07	Heliox	155	7	8	56	5
	06 to 10/08	Heliox	125	5	8	40	6
	15 to 23/08	Heliox	155/125	9	8	72	7
	01 to 07/12	Heliox	155	7	8	56	8
<b>Total 1975</b>			<b>67</b>	<b>64</b>	<b>536</b>	<b>8</b>	
<b>1976</b>	26/01 to 01/02	Heliox	90	7	8	56	1
	03 to 10/02	Heliox	150	8	8	64	2
	12 to 19/02	Heliox	150	8	7	56	3
	23/02 to 20/03	Heliox	150	26	24	432	4
	22/03 to 02/04	Heliox	90	12	16	192	5
	06 to 09/04	Heliox	90	4	8	32	6
	12 to 18/04	Heliox	150	7	8	56	7
	19 to 23/04	Heliox	90	5	8	40	8
	26/04 to 02/05	Heliox	155	7	8	56	9
	04 to 22/05	Heliox	150	19	24	336	10
	24/05 to 02/06	Heliox	150	10	8	80	11
	15 to 25/06	Heliox	90/125/155	11	16	144	12
	28/06 to 04/07	Heliox	155/90	7	6	42	13
	24/11 to 03/12	Heliox	75/150	10	8	80	14
<b>Total 1976</b>			<b>141</b>	<b>157</b>	<b>1666</b>	<b>14</b>	

(Continued on page 23)

**Table 3 (continued 1)**

History of deep technical experimental dives  
 Conducted by the COMEX Hyperbaric Experimental Centre using saturation diving  
 (1977 - 1980)

Year	Date	Nature of gas	Depth metres	Duration days	Number of divers	Number men / day	Total operations
<b>1977</b>	24/01 to 02/02	Heliox	150	10	6	60	1
	21 to 27/02	Heliox	150	7	6	42	2
	02 to 07/03	Heliox	150	6	8	48	3
	15 to 21/03	Heliox	150	7	8	56	4
	22 to 29/03	Heliox	150	8	8	64	5
	31/03 to 06/04	Heliox	150	7	6	42	6
	08 to 14/04	Heliox	150	7	8	56	7
	29/04 to 03/05	Heliox	150	5	2	10	8
	04 to 13/05	Heliox	150	10	8	80	9
	26 to 30/05	Heliox	90	5	8	40	10
	06 to 14/06	Heliox	90/150	9	10	90	11
	12 to 24/12	Heliox	150/300	13	6	78	12
<b>Total 1977</b>				<b>94</b>	<b>84</b>	<b>666</b>	<b>12</b>
<b>1978</b>	24/04 to 04/05	Heliox	150/60	11	8	88	1
	23 to 30/05	Heliox	100	8	6	48	2
	03 to 08/07	Air	25	6	4	24	3
	11 to 17/07	Heliox	160	7	2	14	4
	11 to 23/12	Heliox	150	13	6	78	5
<b>Total 1978</b>				<b>45</b>	<b>26</b>	<b>252</b>	<b>5</b>
<b>1979</b>	16 to 23/07	Heliox	80	8	6	48	1
	26 to 27/07	Air / Heliox	22	2	4	8	2
	05 to 08/09	Air / Heliox	40	4	5	20	3
<b>Total 1979</b>				<b>14</b>	<b>15</b>	<b>76</b>	<b>3</b>
<b>1980</b>	20 to 22/02	Air	24	3	4	12	1
	12 to 20/03	Heliox	90	9	8	72	2
	05 to 14/04	Heliox	90/150	10	8	80	3
	16 to 17/04	Air	20	2	4	8	4
	10 to 15/06	Heliox	90	6	4	24	5
	13 to 19/08	Air	15	7	4	28	6
	12 to 14/08	Air	15	3	4	12	7
	14 to 23/10	Heliox	150	10	8	80	8
	09 to 20/12	Heliox	150	12	8	96	9
<b>Total 1980</b>				<b>62</b>	<b>52</b>	<b>412</b>	<b>9</b>

(Continued on page 24)

**Table 3 (continued 2)**

History of deep technology experimental dives  
 Conducted by the COMEX Hyperbaric Experimental Centre using saturation diving  
 (1981 - 1983)

Year	Date	Nature of gas	Depth metres	Duration days	Number of divers	Number men / day	Total operations
<b>1981</b>	14 jan.	Heliox	150	1	0	0	1
	15 jan.	Heliox	150	1	0	0	2
	26/01 to 06/02	Heliox	150	12	8	96	3
	20/02 to 03/03	Heliox	150	12	8	96	4
	16 to 21/03	Heliox	55	6	6	36	5
	03 to 15/04	Heliox	150/90	13	8	104	6
	21 to 29/04	Heliox	150	9	8	72	7
	12 to 16/05	Air	12	5	4	20	8
	26/05 to 05/06	Heliox	150/90/55	11	8	88	9
	11 dec.	Air	12	1	2	2	10
<b>Total 1981</b>				<b>71</b>	<b>52</b>	<b>514</b>	<b>10</b>
<b>1982</b>	07 to 08/01	Heliox	90	2	2	4	1
	10 march	Air	12	1	2	2	2
	11 to 16/06	Heliox	300	6	0	0	3
	15 to 26/07	Heliox	155	12	8	96	4
	07 to 22/08	Heliox	125	16	8	128	5
	26/11 to 07/12	Heliox	187	12	6	72	6
	10 to 27/12	Heliox	300/187	18	4	72	7
<b>Total 1982</b>				<b>67</b>	<b>30</b>	<b>374</b>	<b>7</b>
<b>1983</b>	12 to 28/01	Heliox	300	17	2	34	1
	26/02 to 22/03	Heliox	300/150	25	8	200	2
	23 to 26/03	Heliox	100	4	4	16	3
	27/04 to 19/05	Heliox	300/155/150	23	8	184	4
	07 to 12/06	Heliox	100/57	6	2	12	5
	06 to 16/07	Heliox	110/130	11	7	77	6
	29/07 to 02/08	Heliox	130	5	2	10	7
	14 dec.	Heliox	9	1	5	5	8
	15 dec.	Heliox	9	1	5	5	9
	17 to 23/12	Heliox	32	7	8	56	10
	25 to 27/12	Heliox	32	3	4	12	11
<b>Total 1983</b>				<b>103</b>	<b>55</b>	<b>611</b>	<b>11</b>

(Continued on page 25)



**Table 3 (continued 3)**

History of deep technology experimental dives  
 Conducted by the COMEX Hyperbaric Experimental Centre using saturation diving  
 (1984 - 1987)

Year	Date	Nature of gas	Depth metres	Duration days	Number of divers	Number men / day	Total operations
<b>1984</b>	05 to 10/01	Heliox	32	6	8	48	1
	04 to 19/03	Heliox	90/150	16	5	80	2
	23 to 25/03	Nitrox	14	3	2	6	3
	28/03 to 07/04	Heliox	150	11	6	66	4
	07 to 17/04	Heliox	150	11	6	66	5
	24/04 to 04/05	Heliox	150	11	6	66	6
	22 to 30/05	Heliox	150	9	6	54	7
	12 to 21/06	Heliox	90	10	6	60	8
	25/06 to 03/07	Heliox	67/90	9	6	50	9
			<b>Total 1984</b>	<b>86</b>	<b>51</b>	<b>496</b>	<b>9</b>
<b>1985</b>	07 to 09/02	Air	20	3	4	12	1
	18 to 27/03	Heliox	90	10	12	120	2
	18 to 26/08	Heliox	122	9	6	54	3
	30/10 to 01/11	Air	24	3	6	18	4
	2 dec.	Air	24	1	5	5	5
	3 dec.	Air	24	1	5	5	6
			<b>Total 1985</b>	<b>27</b>	<b>38</b>	<b>214</b>	<b>6</b>
<b>1986</b>	21 may	Air	24	1	6	6	1
	18 to 21/02	Heliox	55	4	4	16	2
	11 to 28/03	Heliox	58/130/58	18	8	144	3
	17/04 to 03/05	Heliox	130/50	17	2	34	4
	13 to 17/09	Heliox	34/45	5	6	30	5
	03 to 07/10	Heliox	36	5	2	10	6
			<b>Total 1986</b>	<b>50</b>	<b>28</b>	<b>240</b>	<b>6</b>
<b>1987</b>	27/01 to 02/02	Heliox	100	7	4	28	1
	6 april	Air	13	1	3	3	2
	7 april	Air	13	1	3	3	3
	8 april	Air	13	1	3	3	4
	17 oct.	Air	15	1	4	4	5
	18 oct.	Air	15	1	4	4	6
			<b>Total 1987</b>	<b>12</b>	<b>21</b>	<b>45</b>	<b>6</b>

(Continued on page 26)

**Table 3 (continued 4)**

History of deep physiology experimental dives  
 Conducted by the COMEX Hyperbaric Experimental Centre using saturation diving  
 (1988 - 1992)

Year	Date	Nature of gas	Depth metres	Duration days	Number divers	Number men / day	Total operations
1988	06 to 10/04	Air	14	5	11	22	1
	18 to 23/06	Heliox	77	6	4	24	2
	27/06 to 03/07	Heliox	18	7	4	28	3
	10 to 14/07	Heliox	43	5	10	50	4
	19 to 24/10	Heliox	50	6	7	42	5
<b>Total 1988</b>				<b>29</b>	<b>36</b>	<b>166</b>	<b>5</b>
1989	25 feb.	Air	18	1	3	3	1
	26 feb.	Air	18	1	3	3	2
<b>Total 1989</b>				<b>2</b>	<b>6</b>	<b>6</b>	<b>2</b>
1990	07 to 22/05	Heliox	140	16	6	78	1
<b>Total 1990</b>				<b>16</b>	<b>6</b>	<b>78</b>	<b>1</b>
1991	10 to 15/04	Air	15	6	12	24	1
	18 to 21/04	Heliox	43	4	3	12	2
	24/06 to 03/07	Heliox	110	10	3	30	3
<b>Total 1991</b>				<b>20</b>	<b>18</b>	<b>66</b>	<b>3</b>
1992	19/02 to 15/03	Heliox	125/90/80/40	25	4	100	1
<b>total 1992</b>				<b>25</b>	<b>4</b>	<b>100</b>	<b>1</b>
<b>Total (1973 à 1992)</b>				<b>1006</b>	<b>795</b>	<b>7110</b>	<b>125</b>
<b>means on 20 years</b>				<b>51 d./year</b>	<b>40 div./year</b>	<b>356 m./d./y.</b>	<b>6 op./year</b>

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