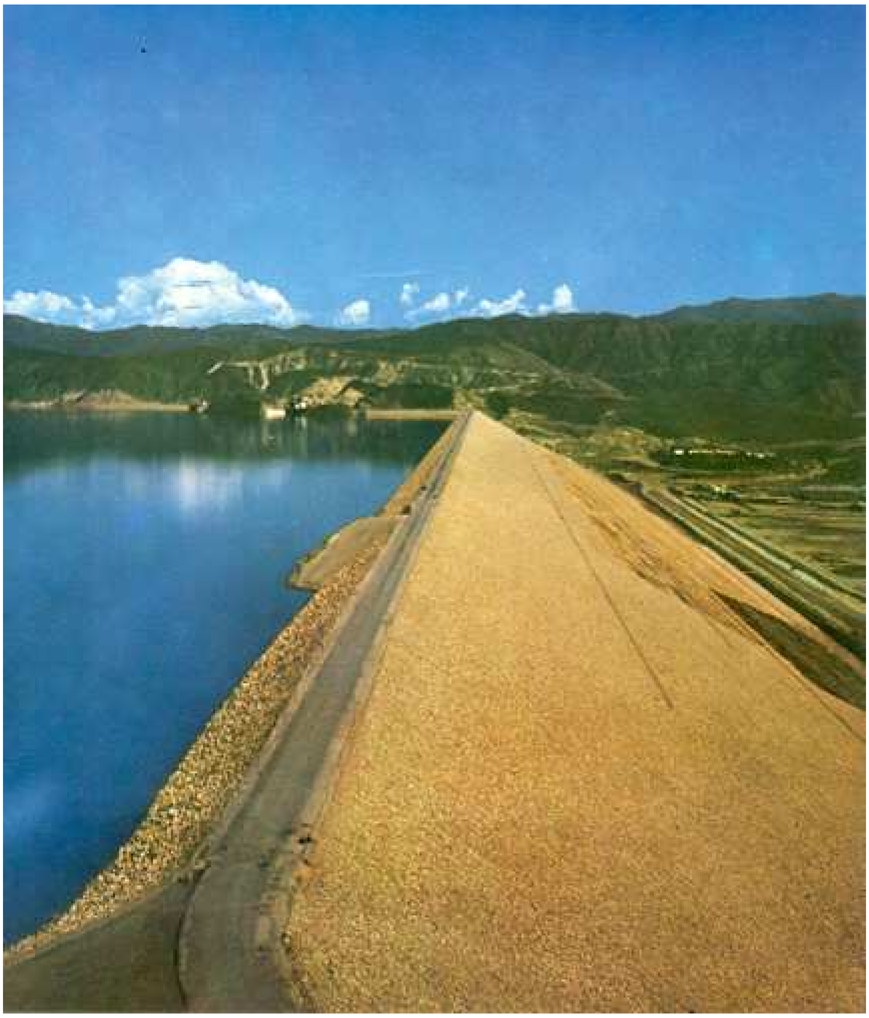
SINMAST DIVERS AT TARBELA

JOB RECORD
N° 5



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TARBELA DAM SITE – PAKISTAN

SINMAST ITALIA's (former name of our Company) diving division, initially developed for the underwater application of our proprietary epoxy compounds, has achieved extensive diving and marine experience thanks to its involvement in the most advanced civil works.
In the last two years paramount effort has been given to cooperate in one of the major engineering projects:

THE TARBELA DAM

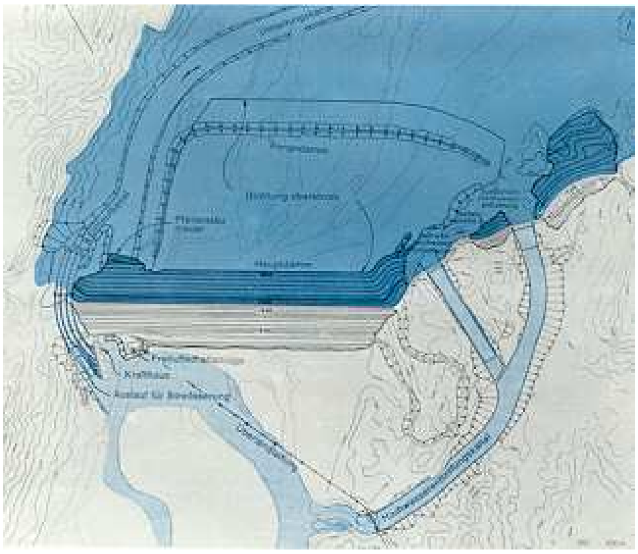
ACKNOLEDGEMENTS

W.A.P.D.A. (Water and Power Development Authority) -	Employer
T.AM.S. (Tippets, Abbett, Mc Carthy, Stratton) U.S.A. -	Consulting Engineers
T.J.V. (Tarbela Joint Venture) -	Contractors

INTRODUCTION

Designed by TAMS (Tippets, Abbett, Mc Carthy, Stratton-New York), U.S.A.) and built by TJV (Tarbela Joint Venture) a group of European contractors sponsored by IMPREGILO (Impresit, Girola, Lodigiani-Milano, Italy), Tarbela Dam, near Rawalpindi (Pakistan) is the world's largest earth and rockfill dam.
The main features of the project are:

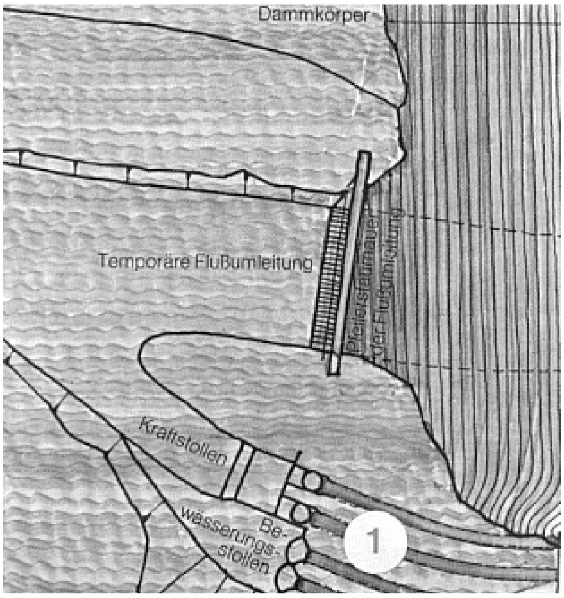
a) A main earth and rockfill dam across the Indus River bed some 2.750 m. long with a maximum height of 146 m. and a total volume of 120.000.000 cu.m.



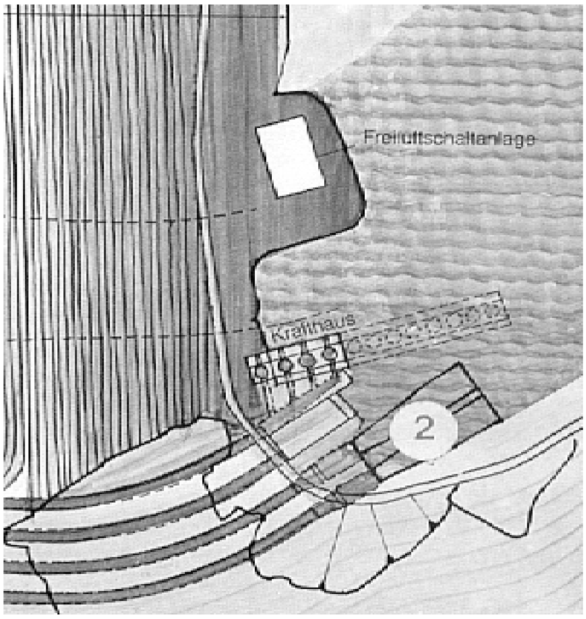
b) Two auxiliary earth and rock fill dams on the left bank with a total volume of 17.000.000 cu.m. enclosing two natural saddles.
c) An impervious blanket upstream of the dam to control the seepage through the foundation with a total volume of 19.000.000 cu.m.
d) Two spillways on the left bank, with a total discharge capacity of more than 42.000 cu.m./sec.
e) Four tunnels through the right abutment having the multipurpose function of diversion, irrigation and power production. Diameters range from 11 to more than 13 meters.

f) A fifth tunnel through the left abutment designed by NESPAK (National Engineering Services of Pakistan) and built by PTC, a Pakistani/TJV Consortium. This tunnel was put into operation in 1976.
Commencing in August 1974 a series of repair works estimated 50.000.000 US$ has been performed by the Contractor. Considerable emphasis was given throughout to complete the repairs as soon as possible so that the irrigation water could be released to benefit the agricultural lands of the Lower Indus Valley.

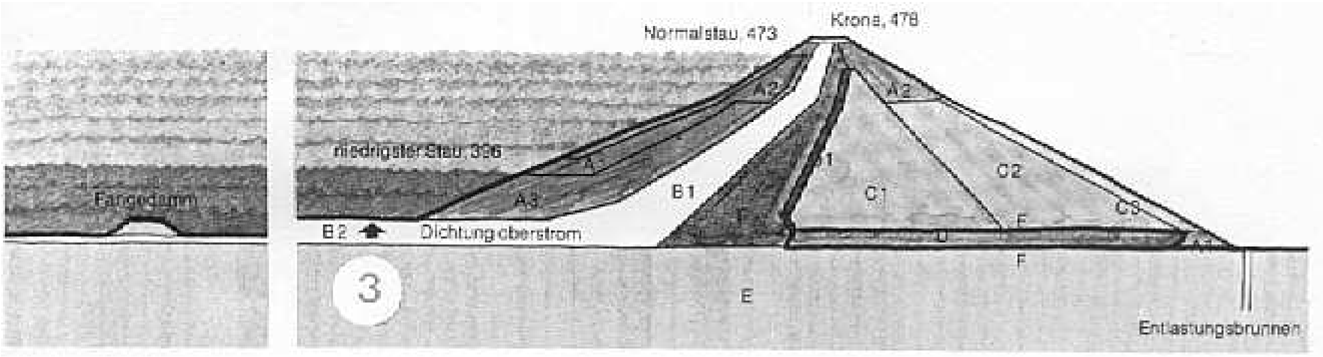
The damages at Tarbela may be divided into 5 main headings:



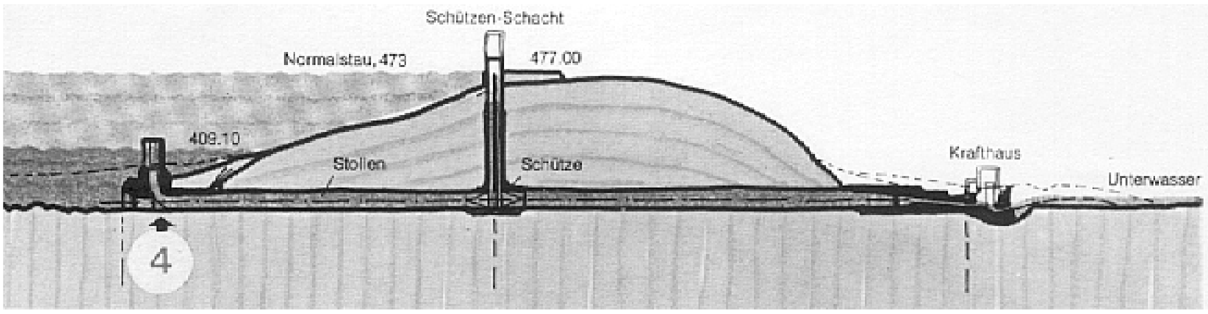
1 the collapse of tunnel 2 close to its intake in August 1974 also resulting in damage to the adjacent tunnel 1 and to the outlets of tunnels 3 and 4, generally due to the emergency draw down of the reservoir.



2 damages to the stilling basins 3 and 4 and the i collapse of stilling basin 3 in May 1975. Damage t stilling basin 3 during second failure in April ’76 follc the completion of the earlier repair.



3 the formation, during the first reservoir filling in 1974 of more than 400 sinkholes in the upstream blanket and of a similar number during the second reservoir filling in 1975.



4 Continuing leakage into the upstream section of tunnel 2 which delayed the completion of the repair work in it.

During this series of mishaps, stretching over a period of more than 2 years, Sinmast Italia provided invaluable services which helped to restore the largest dam in the world to full operational power. *Among them the service provided by Sinmast Divers will be long remembered by the people that lived through those dramatic days.*

1. REPAIRS TO TUNNELS 1. AND 2.

Tunnel 2. The collapsed section during removal o damaged ribs. (Courtesy of Water Power and Construction -June-July 1975)

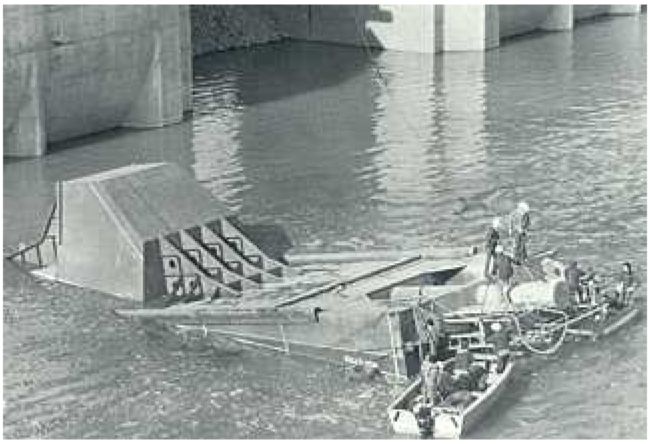
Outlet area. The drawdown. (Courtesy of Water Power and Dam Construction – June-July 1975)

In September 1974 the collapse of tunnel 2 was ascertained and the already partially filled reservoir was completely drained with an emergency drawdown.

In the following months a breathtaking program of repair works developed and a race to put the dam back into operation before the 1975 summer flood took place. An integral part of the repairs to the tunnels 1 and 2 was to ensure that at least 2 of the 3 massive intake gates of each tunnel could again be operated in the event of a second emergency drawdown becoming necessary.

**Tunnel 2. The eroded intake piers and the intake gates.
(Courtesy of Water Power and dam Construction – June-July 1975)**

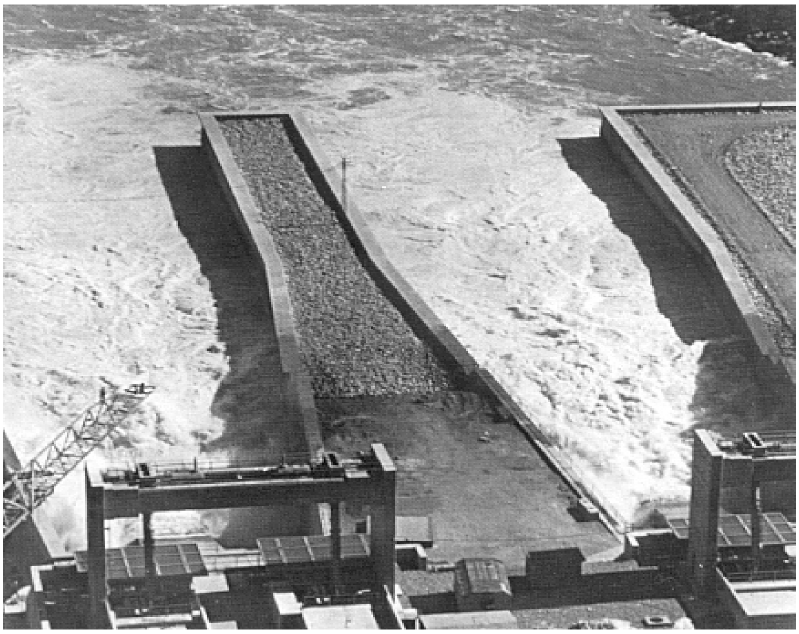
**Tunnel 1. Intake piers after dewatering.
(Courtesy of Water Power and Dam Construction – June-July 1975)**



Intake tunnel 1. Positioning of the barge gate.

While the gates of the more damaged tunnel 2 were to be closed, the central gate of tunnel 1 remained open, to allow the inflow to the reservoir to be discharged. To repair the remaining wing gates, an auxiliary bulkhead was placed downstream of them with the intention of draining the resulting cofferdam with pumps. At the first attempt it was evident that the leakages of the system were far bigger than the pumps discharge capacity.
For the first time Sinmast Divers were called to undertake the difficult job of squeezing into the narrow, 10 m. deep cofferdam, in the completely dark, cold water, to find the origin of the leakage between the huge pumps and below the bottom of the gate.
Both the gate and the concrete structure were in poor condition hindering dewatering. The divers faced the turbulent water in the downstream area of the gate passage to fill the enormous caverns in the invert and in the piers, with sand bags and other suitable material, until the cofferdam was completely drained. Repair work was then completed on two gates of tunnel 2 but only in one gate in tunnel 1. The repair of the fourth gate raised serious difficulties. It had been badly damaged by the earlier uncontrolled passage of water. A decision was taken to remove this gate and replace it. In order to carry out the removal and replacement operation it was necessary to seal the upstream end of the gate passage, so that the repair work inside the tunnel could continue uninterrupted, whilst the inflowing water was diverted in the already repaired irrigation tunnels 3 and 4.
A unique barge gate was designed by Messrs. Interconsult (Milano, Italy) and constructed in the site workshop for this purpose.
The caisson, operated by flooding of buoyancy tanks, was eventually positioned with the help of *Sinmast Divers*, who played an important role both below and above the surface, A few days after the replacement of gate 1 of tunnel 1, the tunnel was returned to full operating capacity and the barge gate was eventually removed.
By their fast successful operation of the huge caisson, weighing about 240 tons, **Sinmast Divers** gained a remarkable reputation for marine expertise in Tarbela

2. DAMAGES TO THE STILLING BASINS OF TUNNELS 3 AND 4

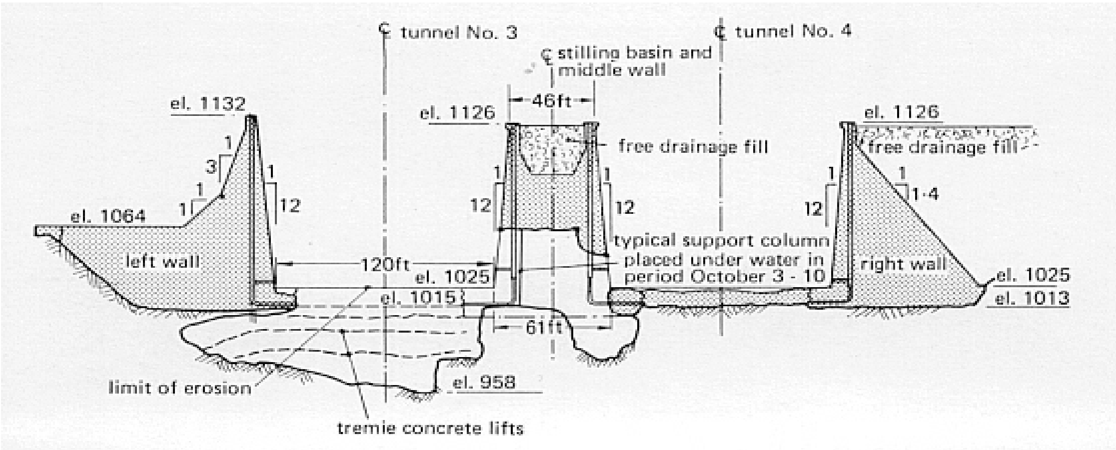


Stilling basins. Tunnels 3 and 4.

The stilling basins of tunnels 3 and 4 are very large reinforced concrete structures, each measuring 185 m. overall length, 35 m. width, by 30 m. depth. Each tunnel is divided, at the downstream end, into two branches, each closed by a radical gate.

During the drawdown of the reservoir in August/September 1974, the outlet gates of tunnels 3 and 4 could not be operated symmetrically, due to damage which suddenly occurred to one branch of each tunnel, during the initial phases of the drawdown. Following the completion of the reservoir draining, the outlet control structures were closed with bulkheads to allow immediate repair work to start.

The stilling basins, however, were quickly silted up with 15 m. of sand and debris and inspection of the basins floor was not practical at the time.
In February 1975 tunnels 3 and 4 were again opened, sweeping out the silt deposits. Later on, sounding surveys indicated there had been major erosion of the floor of both stilling basins. Sinmast Divers were called into action to carry out inspections of the basins. Working in 25 m. of water with zero visibility, all inspections were by touch only. Deposite this, and the size of the damaged areas, they were able to provide very detailed information.
Due to the pressing need of irrigation releases, tunnels 3 and 4 and their stilling basins remained in operation throughout the next three months, with Sinmast Divers providing continuous inspections and surveys. The details of these were to prove to be consistently accurate.
On 15 August 1975, the flow characteristic in the stilling basins suddenly altered with solid waves of water passing over the walls. By dawn, on the following day, fragments of concrete and other debris were seen flying from the very turbulent discharge.
The outlet gates of the tunnels were closed and Sinmast Divers called in to carry out an inspection of both stilling basins. Again working with zero visibility they were soon able to report that large areas of the floor slabs of stilling basin 3 had been broken up and swept away, and that a huge cavern had developed below the slabs. Facing the complete darkness, the unknown shape of the remaining structure and the huge debris dangerously leaning on the working area, the divers were able, after few days, to plot the outline of this cavern.

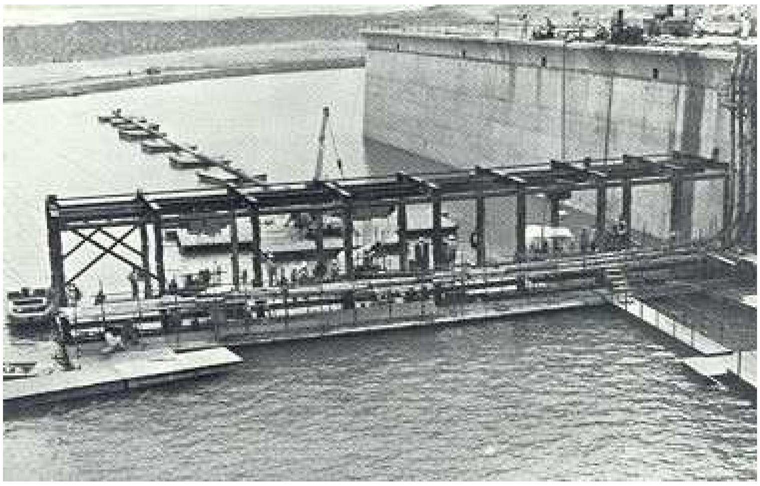


Stilling basins. Tunnels 3 and 4. Typical section showing the limits of erosion. (Courtesy of Water Power and Dam Construction-January 1976)

Continued inspections revealed that both side walls of stilling basin 3 had been seriously undermined. To ascertain the extent of the damage, the divers were forced to dive as much as 45 m. and to traverse 15 or 18 m. below the overhanging walls, to plot the outline of the eroded foundation.

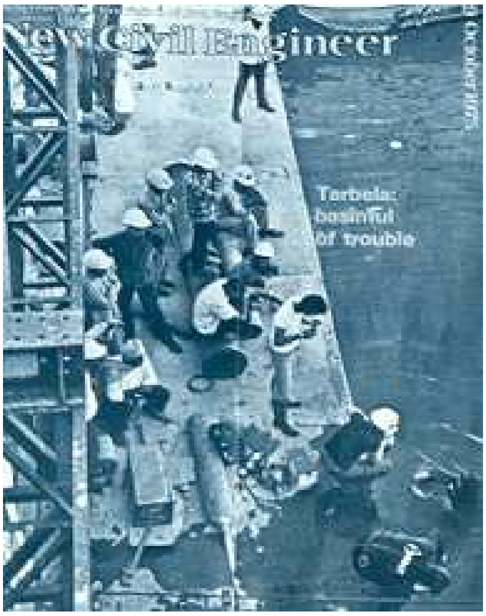
Stilling basins. Tunnels 3 and 4. eroded cavern below the middle wall.

The climax was reached when they eventually located a passage of erosion through the dividing wall between the stilling basins, and where able to swim from one basin to the next, thus proving that the dividing wall was spanning like a bridge over the missing foundation, for a total length of more than 75 m., and that a huge portion of the concrete monoliths had collapsed on the bottom of the cavern. Once the general picture of the erosion had been established for planning the repairs, Sinmast Divers were utilized to carry out an accurate underwater survey.
From the information provided by our team, it was realized that only the fortuitous keying together of adjacent wall monoliths was preventing a total collapse of the walls overlying the deepest erosion. It quickly became apparent that the stilling basins could not be safely dewatered without first filling the eroded area with some structurally suitable material. A tremie concrete solution was eventually selected.



Stilling basins. Tunnel 3. Tremie concrete pontoon.

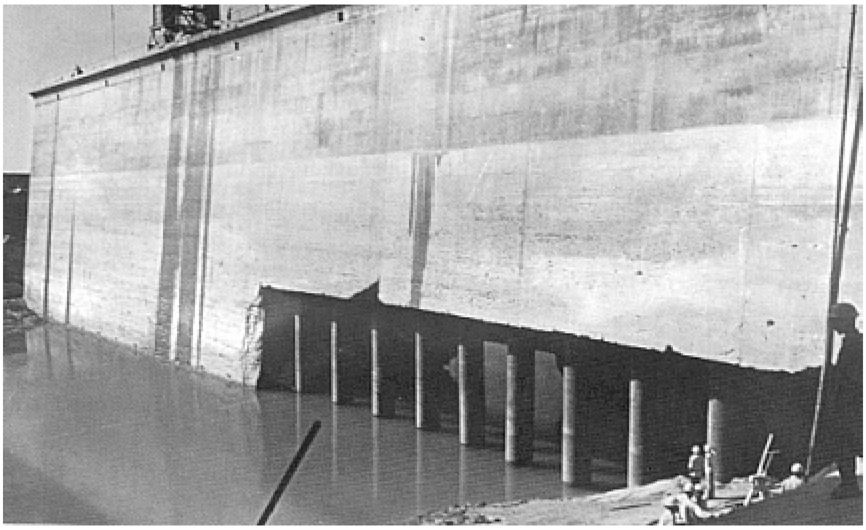
What was to prove to be the world's largest ever tremie concrete operation of cu.m. 43.000 commenced on 15 September and was completed by 15 October 1975. An efficient and accurate underwater monitoring system of the whole operation was provided by Sinmast on a round-the-clock basis. Sinmast Divers were used both to assist in the work of fixing and operating tremie tubes and also to provide factual observations on the actual placement of the concrete.



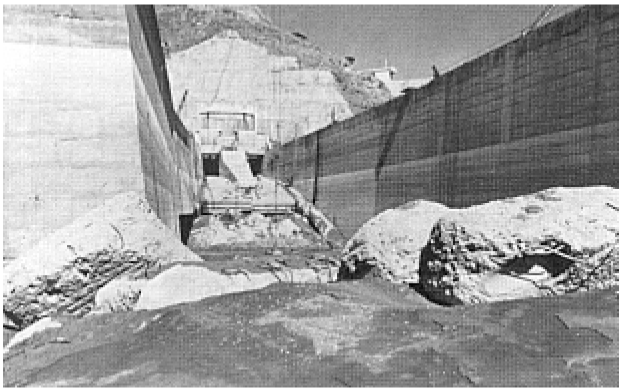
Stilling basins. Tunnel 3. Cover picture of the NEW CIVIL ENGINEER of October 9.75, showing the tremie concrete pontoon, and Sinmast Divers at work.

This provided the supervisor with the fullest knowledge of the pour progress, to enable him to take such action as might necessary. With the completion of the tremie operation, the next step was to underpin the dividing wall so that the basins could be safely dewatered. Nine prefabricated steel piles, each 1.5 m. dia. and about 12 m. long, were suspended by Sinmast Divers under the wall, directly beneath a series of existing 200 mm. dia. drain holes. The tubes were then filled with tremie concrete dropped through the drain holders: rubber skirts were fitted at the top of the tubes to prevent leakage of grout.

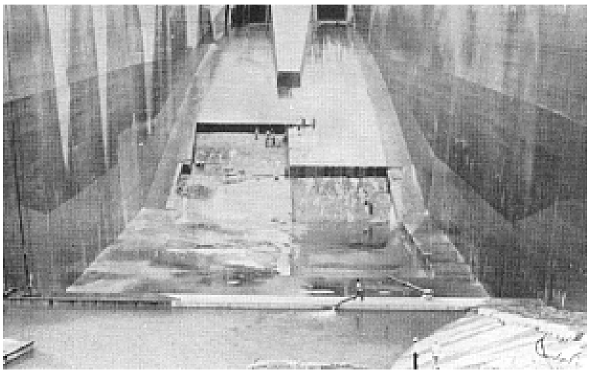
With the satisfactory completion of this operation, it was possible to, very cautiously, dewater the stilling basins. The damage was massive. Much work was necessary to restore the structures. However, the accurate information supplied by the Sinmast Divers' survey team was already available for planning to proceed. The repairs could now be completed with maximum speed.



Stilling basins. Tunnel 3. The 1.500 m/m dia. steel props installed by the divers to support the undetermined middle wall



Stilling basins. Tunnel 3. After dewatering on nov.75



Stilling basins. Tunnel 3. After dewatering on summer 76

With the completion of the repairs of the damages incurred in 1975, both stilling basins were again put into operation on 21st April 1976. During the following days, Sinmast Divers were called in at regular intervals to assist in monitoring the stilling basins for potential damages.
On 27th April 1976 however, stilling basin 3 again failed. Sinmast Divers again assisted in producing underwater surveys to determine the extent of the damage, and to ascertain that about 2.000 cu.m. of the concrete slabs of stilling basin 3 had been ripped out and swept away. For the second time in few months, the stilling basins were dewatered. Again, the divers' reports proved to have been consistently accurate.

While studies started to reveal the causes of the failure, tunnel 4 was back in operation. Now Sinmast Divers had the task of monitoring it with underwater inspections, until a final dewatering was decided upon, to allow more accurate studies of the damages, and definitive planning of the repair works.

3. REPAIRS TO THE IMPERVIOUS BLANKET

Tarbela Dam is sited on approximately 120 to 150 m. of underlying alluvium. In order to contain the enormous reservoir, an impervious blanket, varying in thickness from 13 to 1.5 meters, was laid down from the main dam to some 1.500 m. upstream.

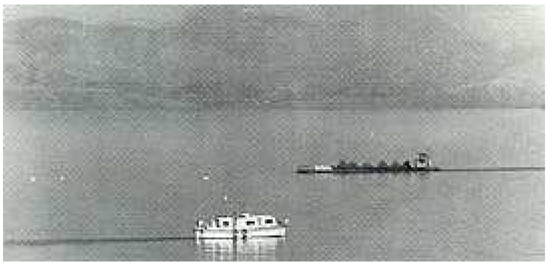
With the completion of the reservoir drawdown, in September 1974, a number of sinkholes were noted in the blanket.

Impervious blanket. Typical sinkhole. (Oct.74)

Sinkholes consist of holes with near vertical sides varying in diameter from 0.6 to 10.0 meters and up to 3.5 m. deep, which have the appearance of having been punched into the protective blanket.

As the water receded, more sinkholes came into view, until a total of more than 400 were logged. These sinkholes were repaired by conventional methods, using trucked-in normal fill.

In the second reservoir filling in 1975, sophisticated sonar surveys carried out by E.G. and G. (Edgerton, Grier and Germeshausen, Environmental Consultant Inc. – Boston, Mass., U.S.A.) detected the formation of new sinkholes.



Dump barges' operation. The survey boat and a dump barge playing the Tarbela reservoir.

This possibility had already been anticipated. Two quick release 125 cu. m. capacity bottom dump barges were on site, ready for operation.

The barges were to be used to transport suitable silty materials to a position directly over the sinkholes. With the quick release operation, it was found that the material would spread over an area of 80 m. diameter around the sinkhole. It was assessed that an average of 50 barge loads were required for each sinkhole, or each closely centred group of sinkholes.

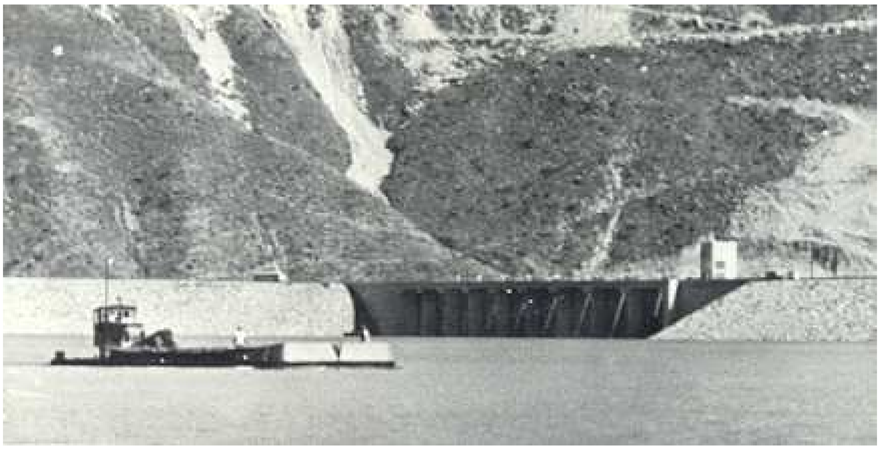
Sinmast Site Representatives were asked to control this operation on a round-the-clock basis, with the main task of improving the production, and maintaining the accuracy of the dumping up to very high standards, to obtain maximum benefit from the 850.000 cu.m. of special material stockpiled for this purpose.

Dump barges' operation. A dump barge before launching.

The Sinmast Barge Skippers, all merchant marine deck officers, soon became very proficient and accurate in the operation of the barges, thus allowing a significant saving of the time and materials.

Advanced ocean research methods and instruments, such as side scan sonar, bottom profiler, echo sounder and a grid of Motorola "MINIRANGER" range finders were successfully utilized, both by E.G. and G., for monitoring the blanket and for the actual results of the dumping, and by Sinmast, to ensure accurate location of the barges'loads.

Dump barges' operation. The loading system.



During operations lasting 14 months, a total of nearly 8.000 barge trips were made, dumping about 750.000 cu.m. of material over more than 450 sinkholes.

Dump barges'operation. A loaded barge. Auxiliary dams and spillways in the background.

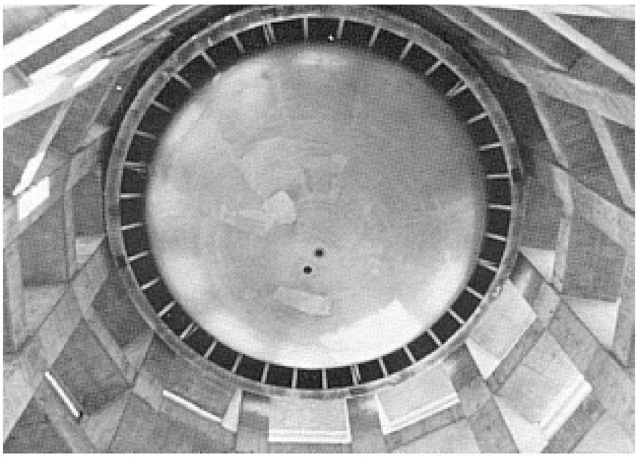
4. DEWATERING AND LEAKAGES CONTROL IN TUNNEL N°2

Following the drawdown of 1974 and the appearance of sinkholes in the upstream blanket, the substantially repaired tunnel 2 was evacuated and pressurized in the remote possibility of a second emergency drawdown being necessary.

By November 1975, the critical period has passed without incident. The dewatering of tunnel 2 was directed to complete the repair works. Initial attempts to dewater the tunnel proved unsuccessful, as leaks of about 1 cu.m. per second had developed under the high reservoir head.

Throughout the use of numerous methods, techniques and specialist to detect and eventually control the leaks, Sinmast Divers played an important role, starting with the very first inspections at the tunnel gates, the underwater operation of the intake hemispherical bulkhead to the tunnels, and, eventually, the installation of a water controlling device on top of the enourmous intake, which had been further damaged by the passage of water around the gate.

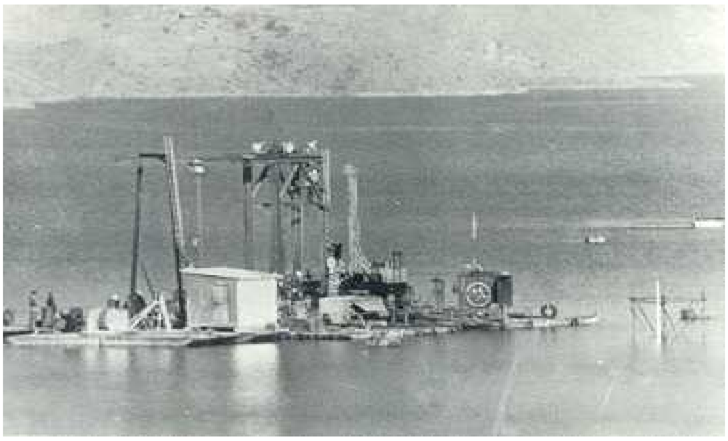
Tunnel 2. The steel – lined downstream



In these efforts, lasting about one year and involving considerable amounts of personnel. Means, and monies the marine expertise and the seamanship of Sinmast personnel proved to be of personnel proved to be of great help in assisting and I assessing all the operations that were carried out, mostly in unfavourable weather conditions, from the surface of the reservoir, such as drilling and grouting, deep water diving, TV inspections, current meters etc.

Intake's hemispherical bulkhead.

Right bank intake area. From left to right: tunnels 1,2,3,4. Note on the intake of tunnels 1 and 2 the temporary framework towers to operate the hemispherical bulkheads.



Right bank intake area. Pontoon for the drilling and grouting of the air vent gallery to control water seepages in tunnel 2.

Sinmast Skippers and Divers took care of most of the marine work. They gave continuous assistance for the precise location of the pontoons, installation of reliable anchorage systems, and safe marine transportation of personnel and materials. Our Site Organization, born out of the need for blanket repairs with the dump barges, proved to deserve its name of Marine Operations section.

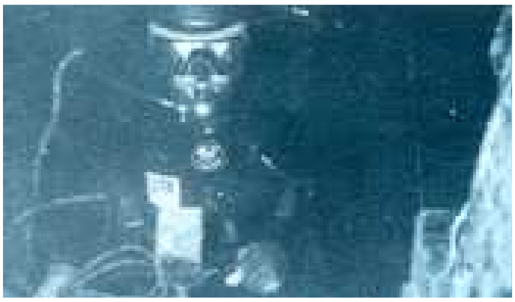
Base to underwater and marine operations.

GENERAL DIVING AND MARINE SERVICE

Intake tunnel 2. Divers operating the hemispherical bulkhead

Intake tunnel 2. Installation of an hydraulic actuators system.

Intake tunnel 2. Hand operation of the hemispherical bulkhead's hoists



A diver working at the hemispherical bulkhead hoists.

During all of this hectic period, Sinmast provided varied and numerous services, in the spirit of strict cooperation with the Client to fulfil the often unforeseen needs of each particular situation.

Over a period of about one year, the intake structure hemispherical bulkheads were opened and closed several times. This, despite the fact that the structure where the winches were to be operated remained submerged, hindering the possibility of normal "dry" operations. Such adverse circumstance was installed, removed, maintained, hand or power operated the 600 kg. Heavy screw jacks provided to open and close the bulkheads and who inspected the structure and the mechanism of the hoists in depths of even 200 ft. of dark, silty water.

Among other miscellaneous services provided, we also mention: handling and marine transportation of 40 tons heavy stop longs; underwater burning & cutting; pipefitting and metal carpentry; searching for leaks and sinkholes near the earth fill cofferdams; positioning, removal and operating of pumps, air lifts, pipe lines, valves, inspection of leaking gates and structures below or above the water; providing assistance in working in gas polluted environment; caulking, sealing, cleaning and repairing underwater structures; search and recovery of lost materials.

All those services were carried out successfully without delays, under difficult, inclement conditions.

Auxiliary spillways area. 40 tons intake stop longs suspended at the service pontoon.

During the repair works of Tarbela Dam, Sinmast Underwater and Marine Organization has been working in cooperation with Technicians and Engineers of the following world wide renowned companies:

W.A.P.D.A. (Water and Power Development Authority) Pakistan
T.A.M.S. (Tippetts, Abbett, Mc Carthy, Stratton) U.S.A.
T.J.V. (Tarbela Joint Venture) formed by the following partners:
IMPREGILO (Impresit Girola Lodigiani) SpA, Italy – Sponsor
COGEFAR (Costruzioni Generali Farsura) SpA, Italy
IMPRESA ASTALDI ESTERO, Italy
C.C.I. (Compagnie de Constructions Internationales), France
C .F.E. (Compagnie Française d'Etreprises), France
SPIE – BATIGNOLLES, France
HOCHTIEF AG, Germany
PHILIPP HOLZMANN AG, Germany
STRABAG BAU AG, Germany
ED. ZÜBLIN AG, Germany
SA CONRAD ZSCHOKKE, Switzerland
LOSINGER AG, Switzerland
C. BARESEL AG, Germany

NESPAK (National Engineering Services Ltd), Pakistan
- Consulting Engineers for the Left Bank irrigation Tunnel

P.T.C. (Pakistan Tarbela Consortium) formed by:
N.C.C. (National Construction Company) Pakistan
T.J.V. (Tarbela Joint Venture)
- Contractors for the Left Bank Irrigation Tunnel

HARZA ENGINEERING COMPANY INTERNATIONAL, U.S.A.
- Consulting Engineers

Sir ALEXANDER GIBB & ASSOCIATES, England
- Consulting Engineers

D. GRAY & ASSOCIATES, England
- Mechanical and Electrical Quantity Surveyors

ING. GIOVANNI RODIO & C., Impresa Costruzioni Speciali SpA, Italy
- Drilling and Grouting

EM - HIDROMAONTAZA, Jugoslavia
- Mechanical and Electrical Intallations

SO.RE.FA.ME. (Sociedades Reunidas de Fabricaçôes Matalicas) S.A.R.L., Portugal
- Service Gates Supplier

HITACHI SHIPBUILDING AND ENGINEERING COMPANY Ltd., Japan
- Hemispheriacal Bulkhead Supplier

E.G. & G. (Edgerton, Grier and Germeshausen) Environmental Consultant Inc.
- Marine Geophisical Surveys

STRONGWORK DIVING (International) Ltd., U.K.
- Underwater Activities

I.U.C. (International Underwater Contractors), U.S.A.
- Underwater Activities

D.W.E., Deggendorfer Werft und Eisenbau Gesellschaft, MBH, Germany
- Dump Barges Supplier

INTERNCONSULT, Italy
- Barge Gate Designer

MARINE PAINTING, Switzerland
- Main Painting Subcontractor

Sinmast Italia while operating with its divers was as well engaged in the extensive repair works of concrete structures utilizing its specialized personnel and its proprietary epoxy compounds: P.A. 103, L.A. 2S, Injection 1, E/2, Subcom T.260, # 108 Mortar. The value of special material utilized at Tarbela was exceeding 3 million Euros as at today.

DESCRIZIONE DELLE OPERE