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Meeting Paper

Combined Storage of Natural Gas and Potential Electrical Energy in Compensated Caverns

by

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Combined storage of natural gas and potential (electrical) energy in compensated caverns.

by Eke Verschuur, Shell Research

Shell has developed a compensated cavern system for the combined storage of natural gas and potential (electrical) energy. The Dutch utility (SEP) is seriously considering to build a demonstration unit which can deliver 1700 MWh_e per day at a rated output of 110 MW.

The concept could potentially deliver 100 million sm^3 of natural gas per day to the grid simultaneously with the electrical power. Re-charging with gas and electricity occurs overnight. The demonstration phase will focus on the electricity storage only.

To store potential energy brine is displaced, with 220 bar gas, from the lower (-1600m) cavern (500.000 m^3) into the upper (-600m) cavern (1.000,000 m^3).

The working gas is stored in the upper cavern at 130 bar when the system is discharged. The gas is transferred by a piston engine which will be derived from the World's largest diesel engine SULZER's RTA 84.

The system operates under (almost) adiabatic conditions and has a high efficiency (80%). Instead of natural gas inertized air (8% O_2) can be used.

The paper will focus on the design, thermodynamical and geomechanical aspects of the underground works.

A particular feature of the design is the conceptual horizontally leached tunnel (6 m diam., length 250 m) to connect the vertical brine shafts.

The actual construction of this tunnel is in essence the only part to be demonstrated.

A decision how to build this tunnel has not been made.

We take this opportunity to solicit contributions from participants of the meeting.

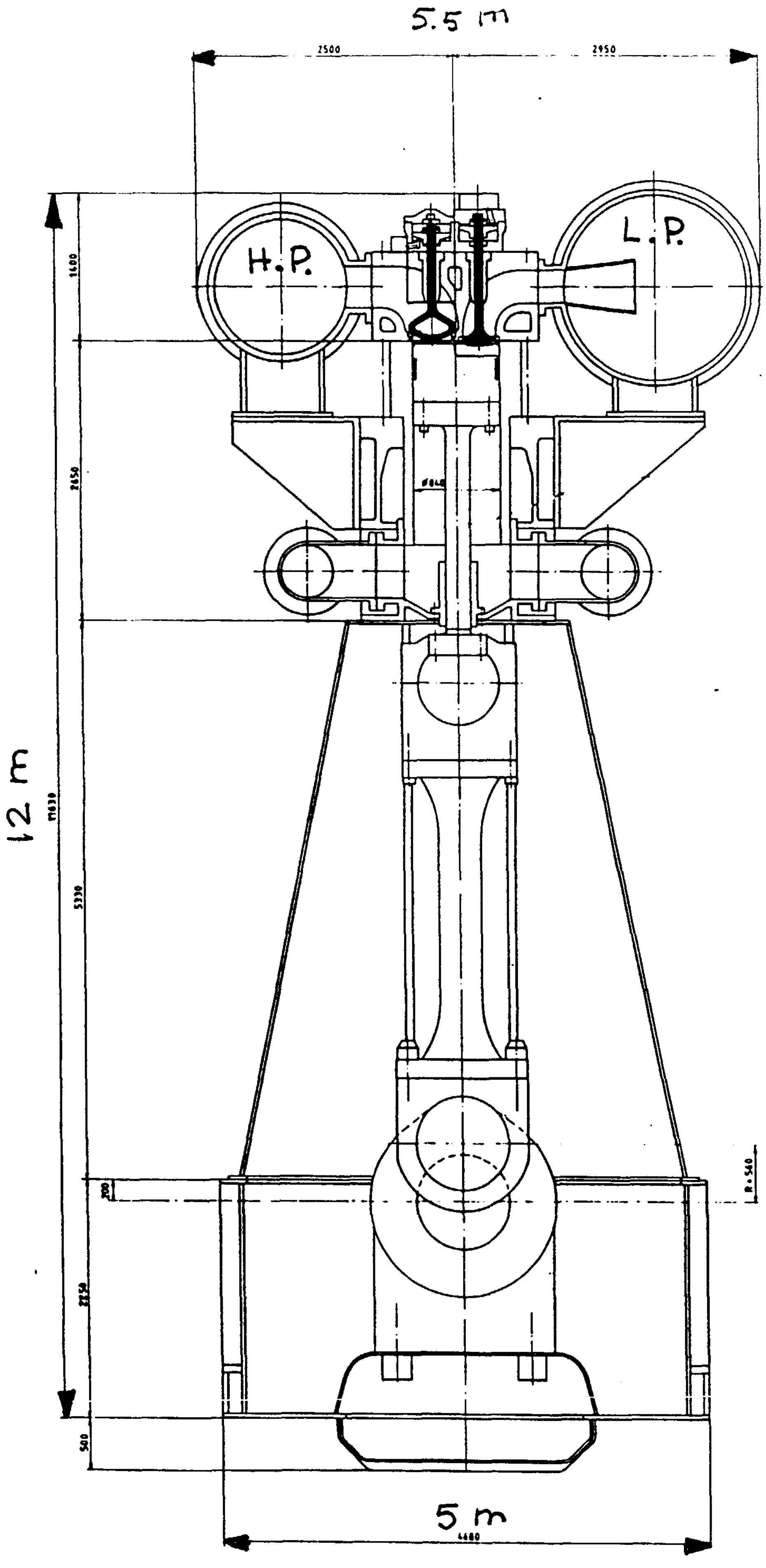
SUCCESS

SHELL UNDERGROUND COMPENSATED CAVERN ENERGY STORAGE SYSTEM

A NOVEL FACILITY FOR THE SIMULTANEOUS STORAGE OF POTENTIAL (ELECTRICAL) ENERGY AND CHEMICAL (NATURAL GAS) ENERGY

*

slides presented at SMRI
Paris 14-18/10/90



5.5 m
2500
2950
H.P.
L.P.
1600
2650
12 m
11630
5330
2250
200
500
R=540
5 m
4680

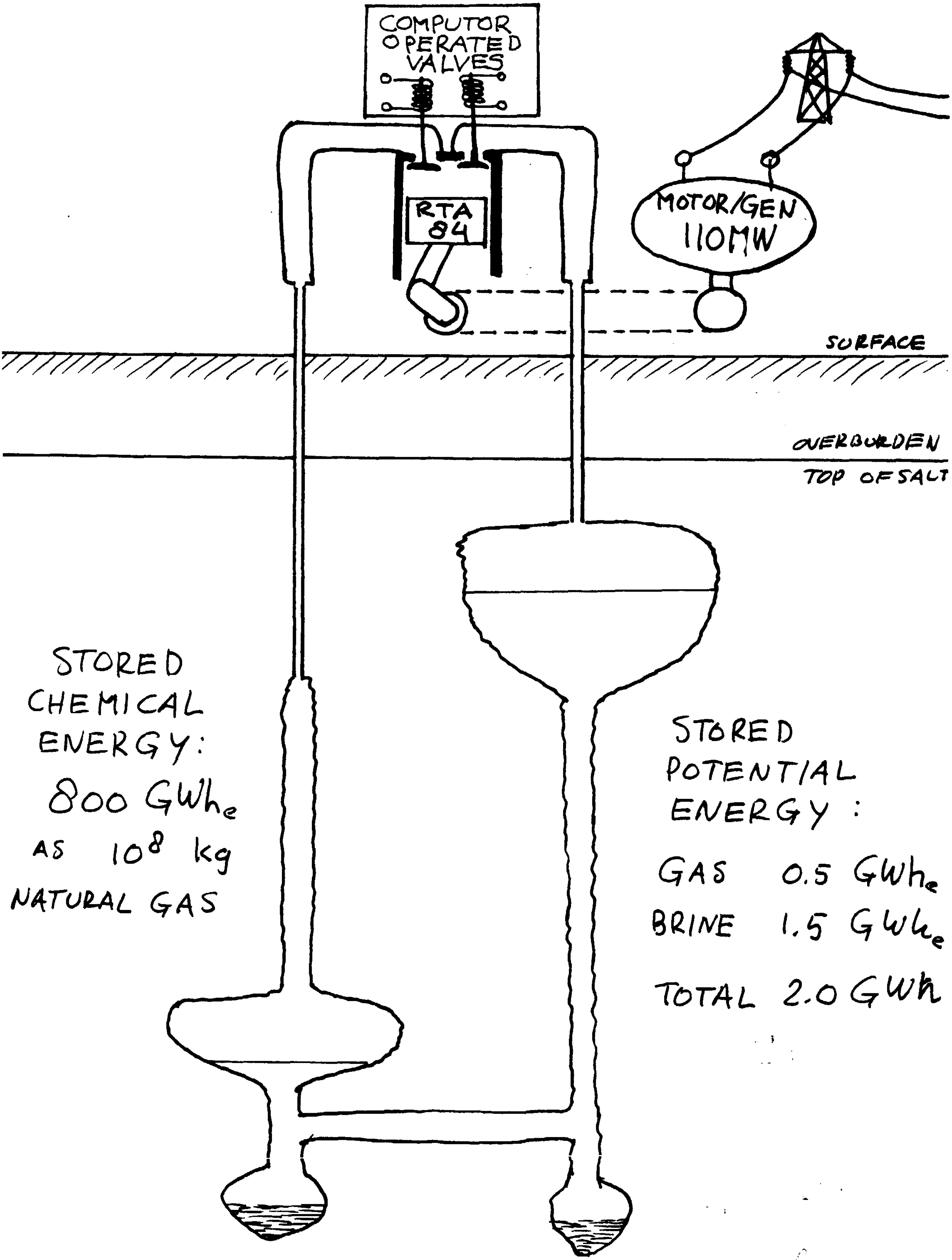
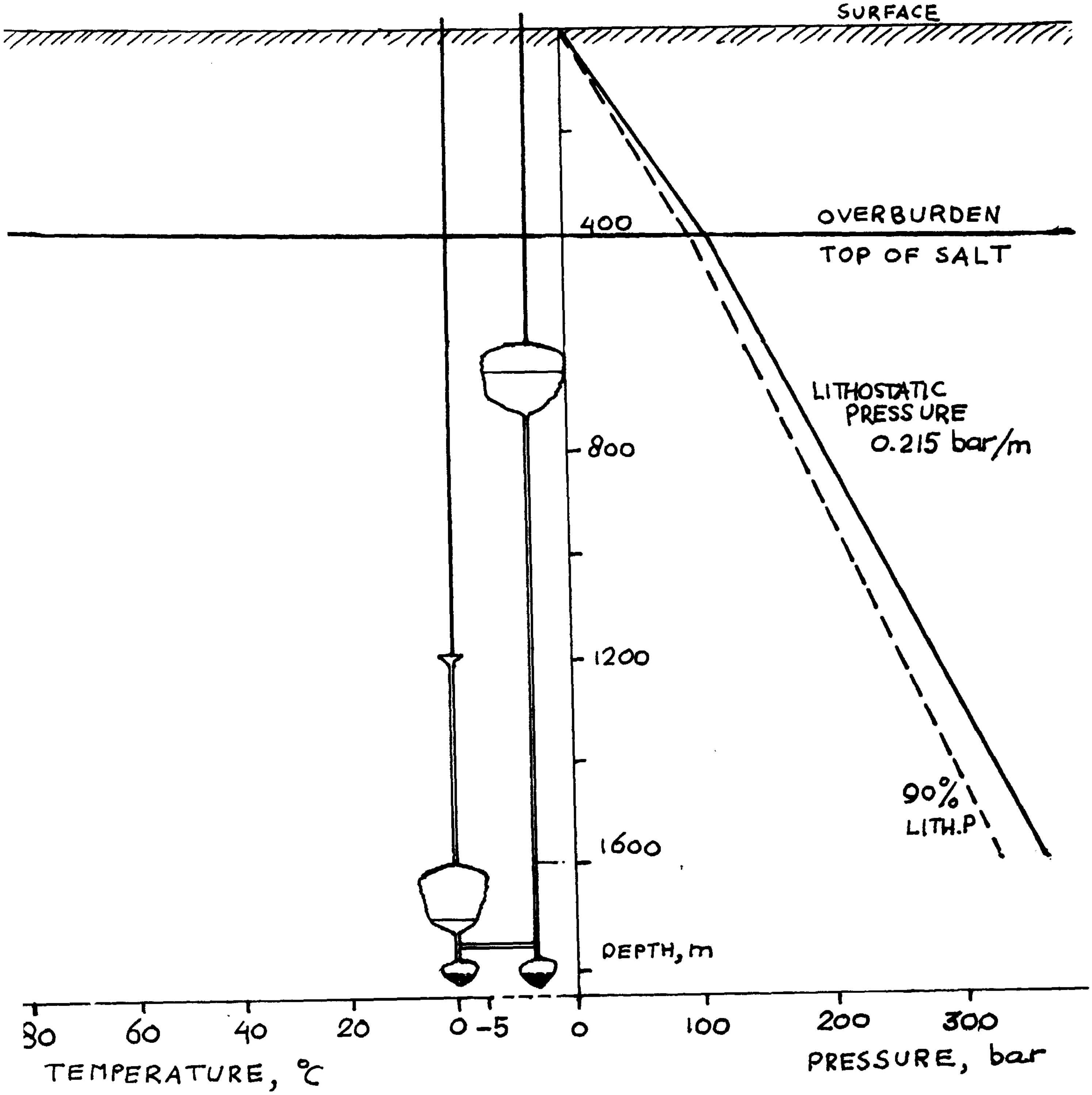
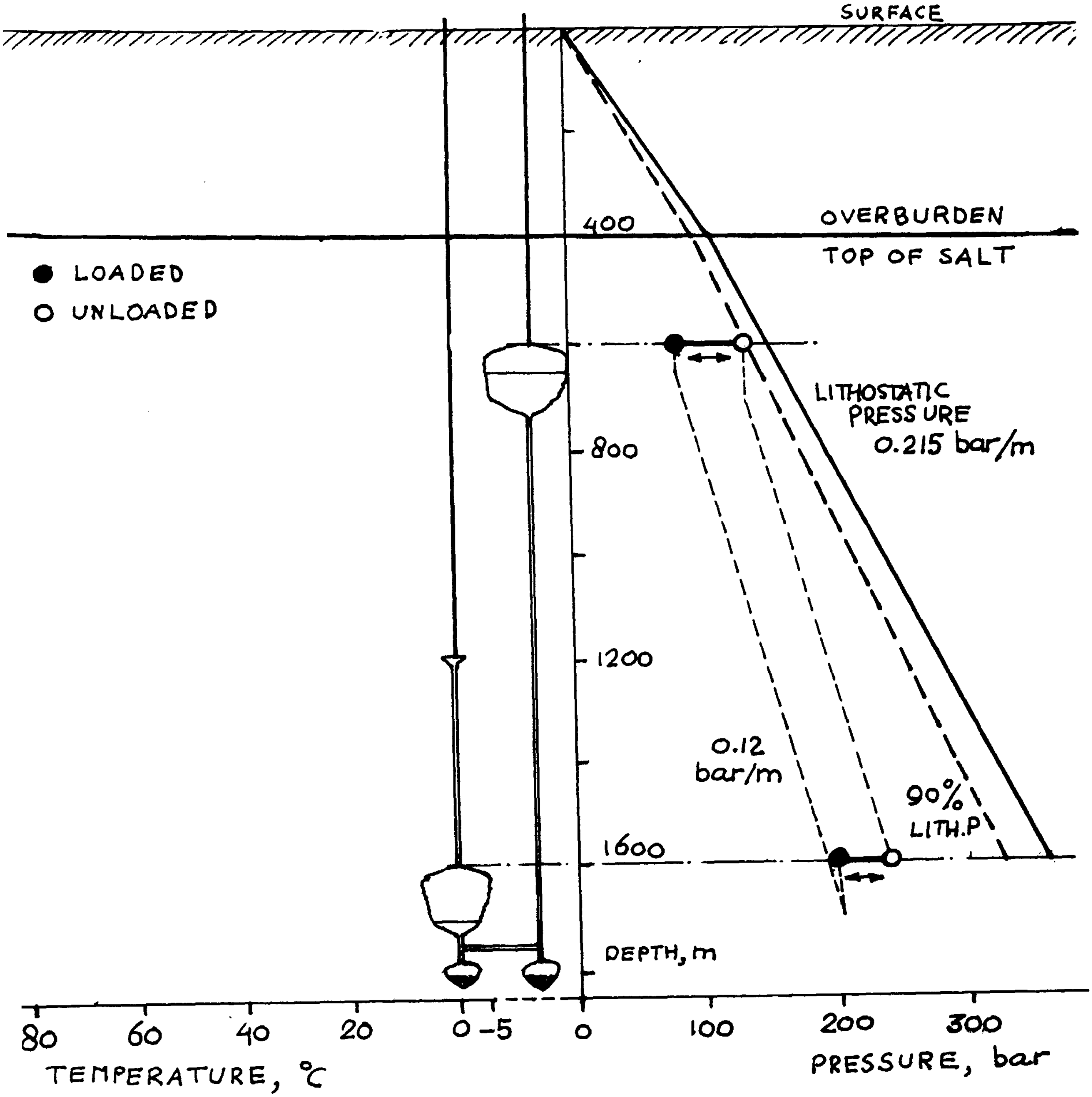

COMPUTOR OPERATED VALVES
RTA 84
MOTOR/GEN 110MW
SURFACE
OVERBURDEN
TOP OF SALT
STORED CHEMICAL ENERGY:
800 GWh$_e$
AS 10^8 kg NATURAL GAS
STORED POTENTIAL ENERGY:
GAS 0.5 GWh$_e$
BRINE 1.5 GWh$_e$
TOTAL 2.0 GWh

fig 2

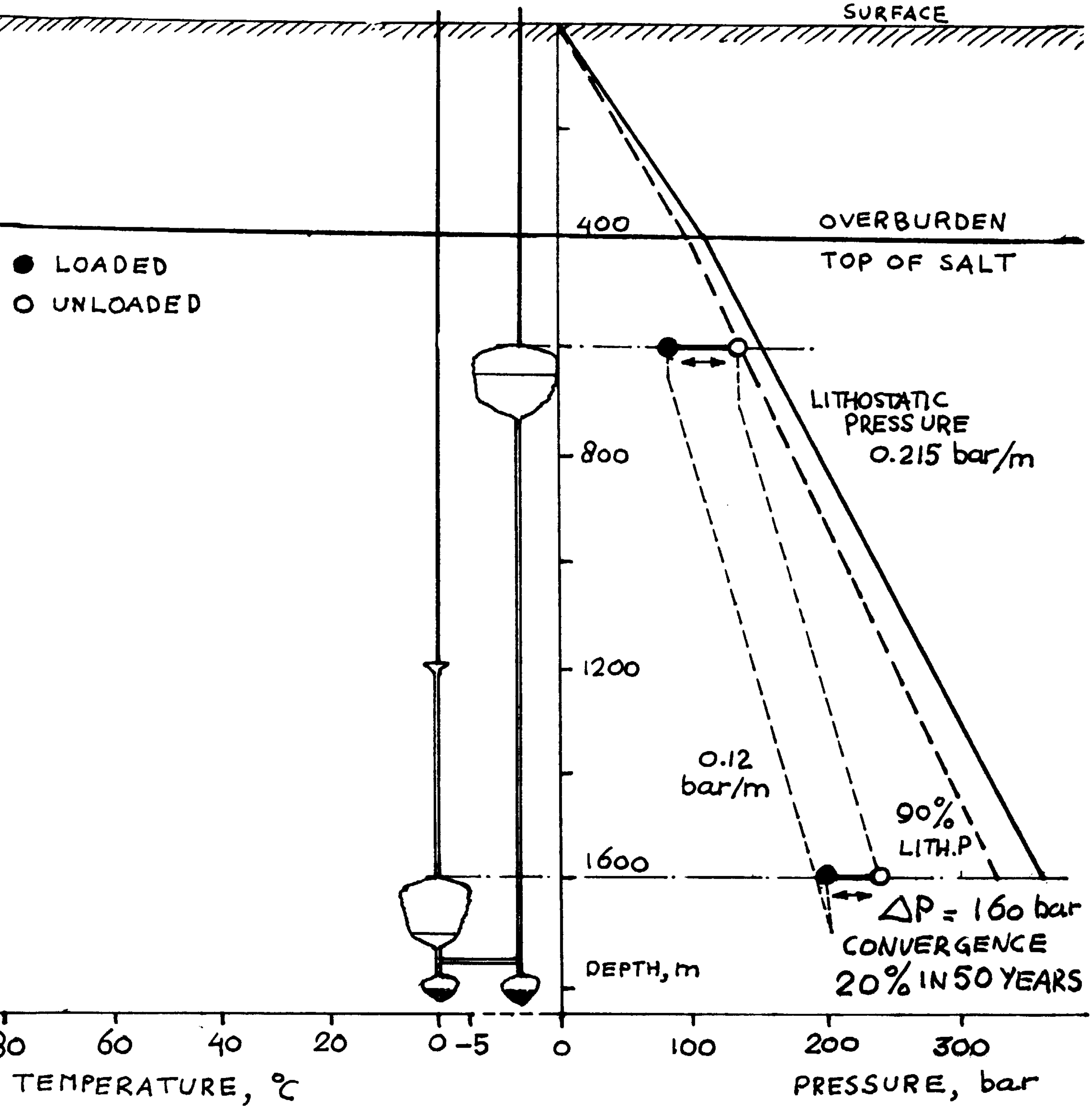


SUBSURFACE PRESSURES AND TEMPERATURES

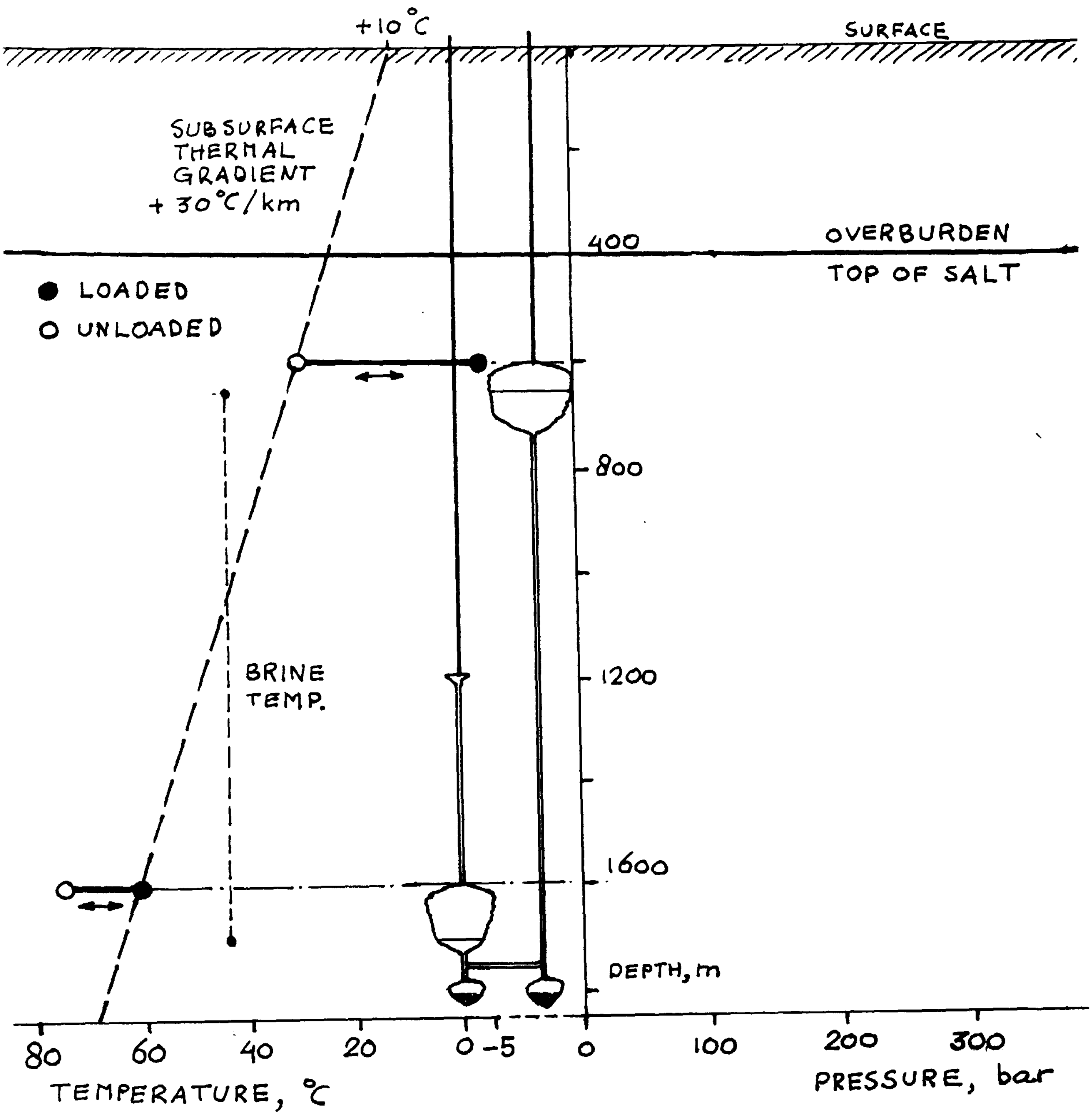
fig. 8



SUBSURFACE PRESSURES AND TEMPERATURES

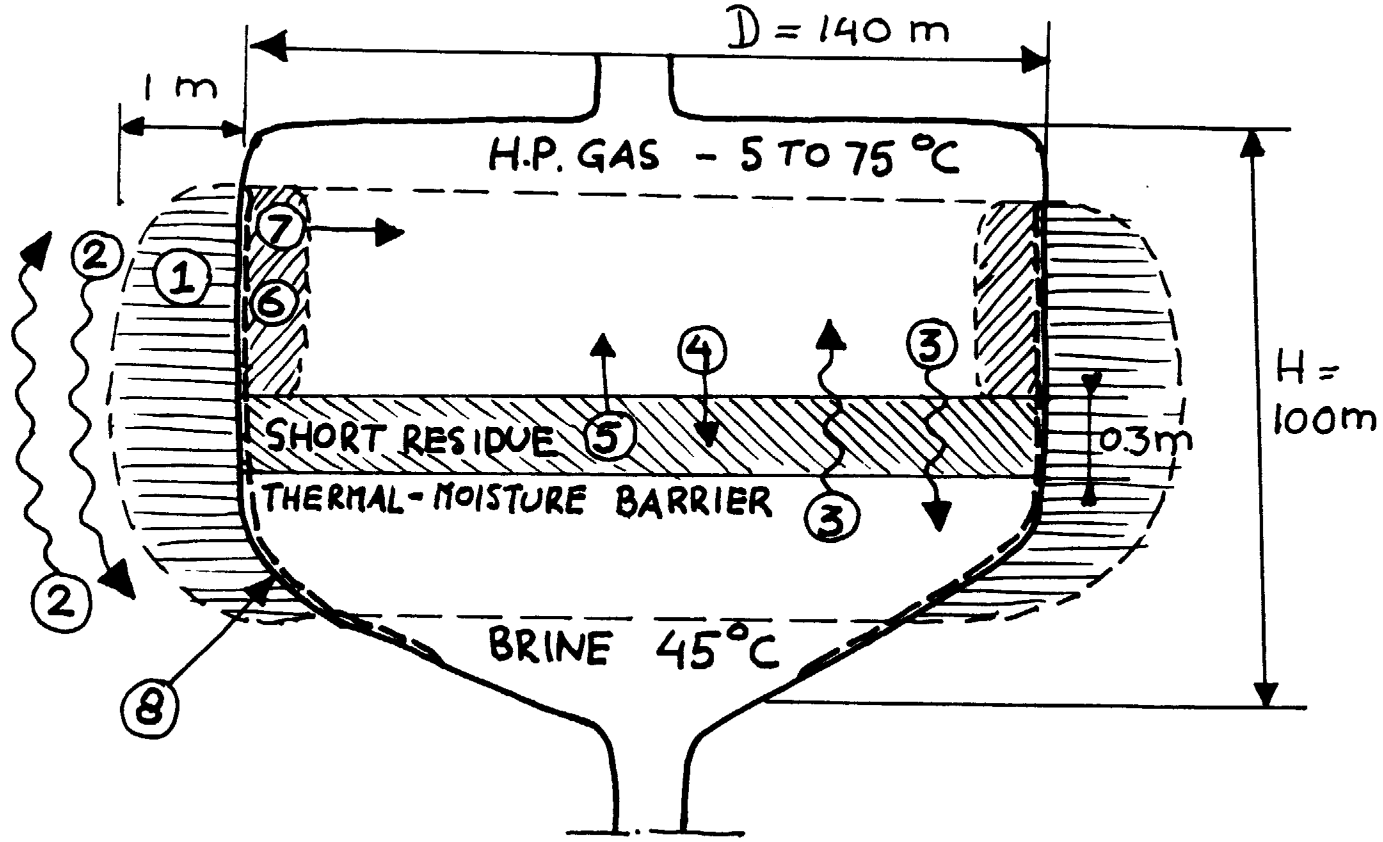


SUBSURFACE PRESSURES AND TEMPERATURES



SUBSURFACE PRESSURES AND TEMPERATURES

RESULTS EXPERIMENT / CALCULATION



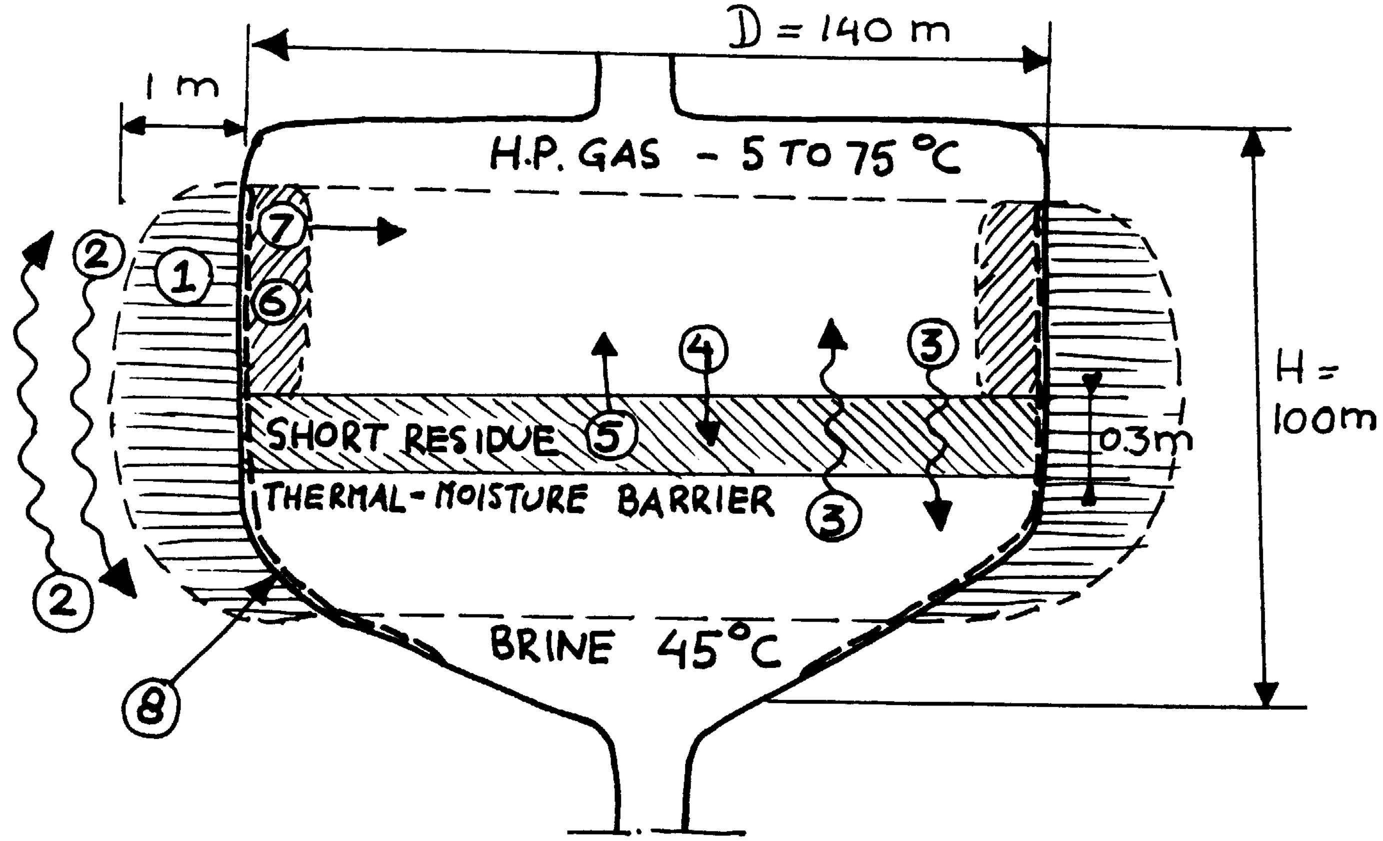
(1) WALL HEAT PENETRATION DEPTH, ~1 m

(2) WALL HEAT LEAK, 300 GJ PER DAY, CYCLE
= ENERGY LOSS 0.45 %

(3) HEAT LEAK THROUGH BARRIER,
30 GJ/DAY = ENERGY LOSS 0.05 %

TOTAL ENERGY LOSS, 0.5 % = ALMOST ADIABATIC

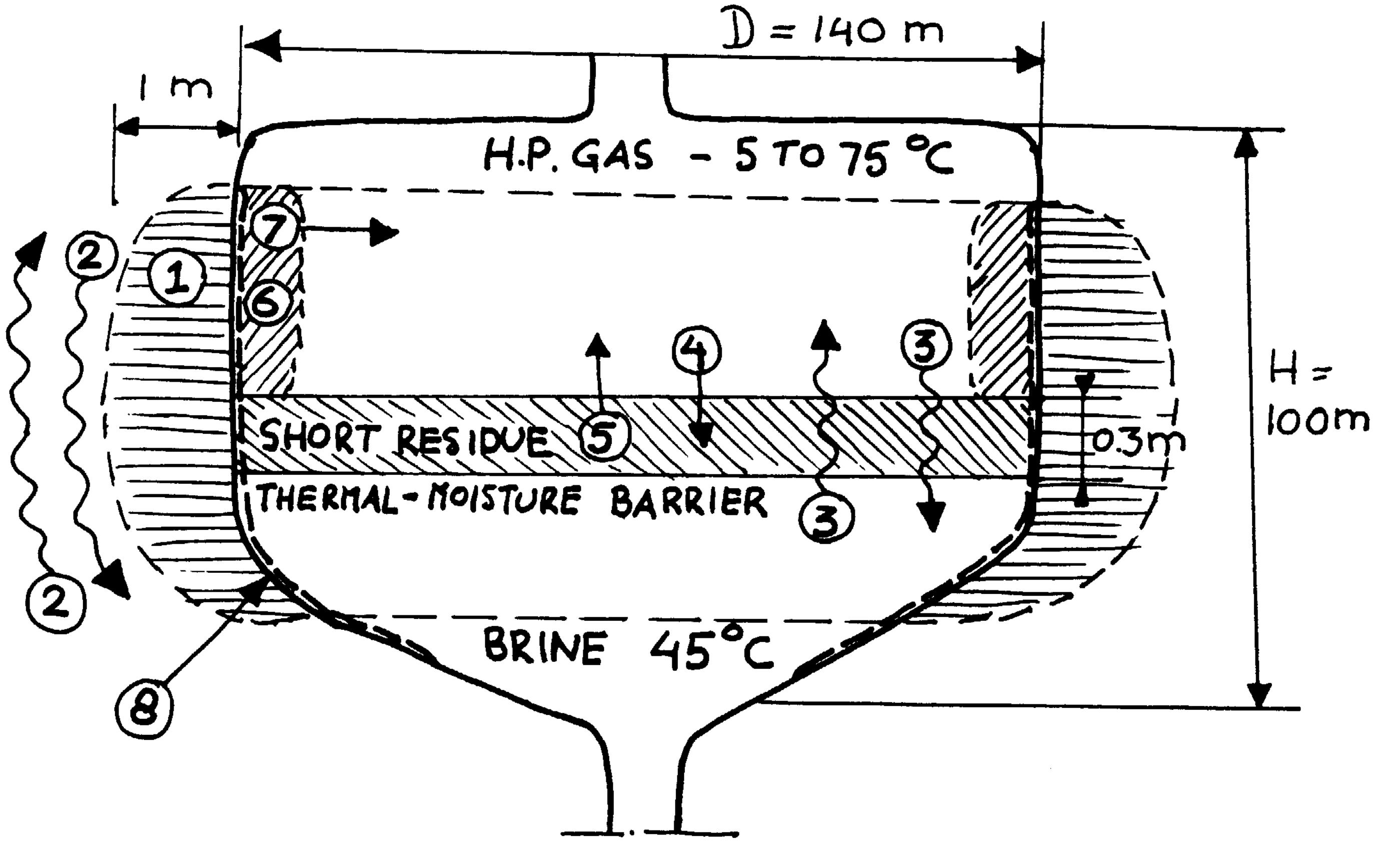
RESULTS EXPERIMENT / CALCULATION



④ GAS DISSOLVED IN BARRIER, 2 %w

⑤ VAPOUR, FROM BARRIER, INTO GAS, 10 PPM

RESULTS EXPERIMENT / CALCULATION

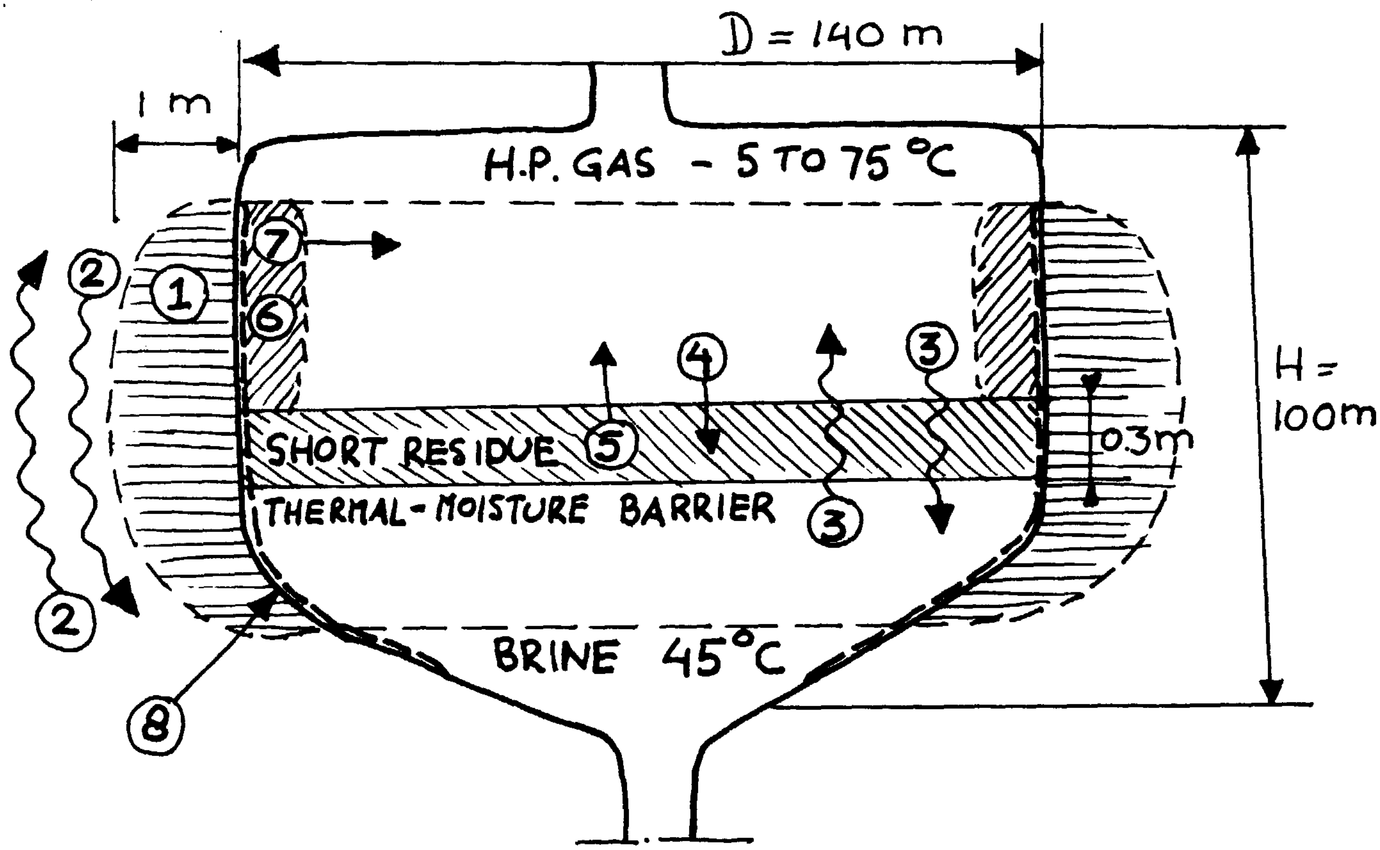


⑥ 40 MICRON WATERFILM RETAINS AT WALL

⑦ FILM VAPOURIZES COMPLETELY DURING EACH CYCLE :

- EQUALS 2 TONNE / CYCLE
- ADDS 10 PPM TO THE GAS
- REQUIRES 4 GJ / CYCLE

RESULTS EXPERIMENT / CALCULATION



⑧ MOST UNUSUAL RESULT :

WITH OUR PROPRIETARY ADDITIVE OIL COULD BE MADE TO WET THE SALT WALL !

STORAGE RELATED COSTS, NLG $\cdot 10^6$

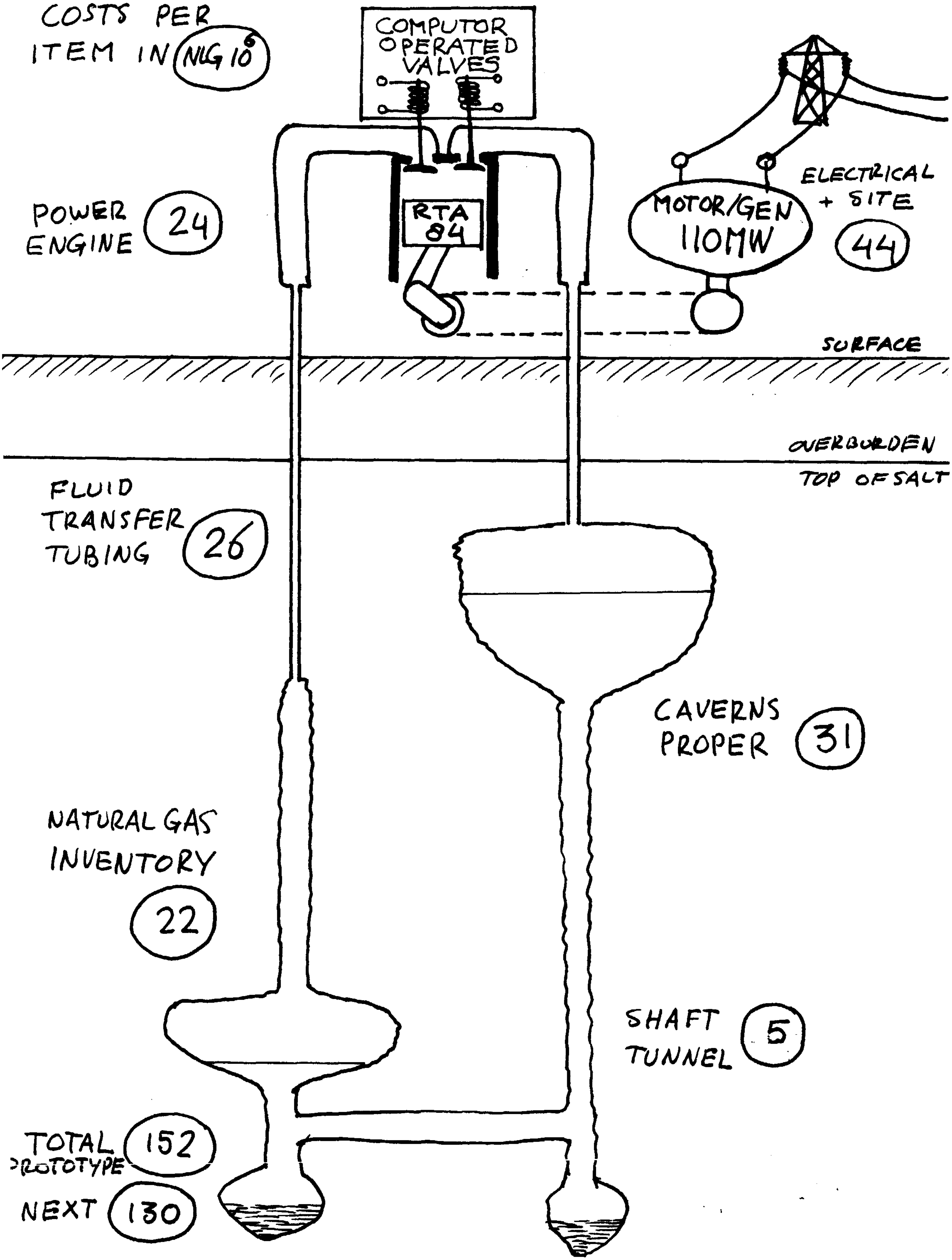
	CONV. PUMPED HYDRO, 20 GWh	SUCCESS, 2 GWh PROTOTYPE		
RESERVOIRS	400	31	÷	0
SHAFTS / TUNNELS	200	5	÷	5
GAS INVENTORY: - NATURAL GAS	N.A.	22		-
- INERTIZED AIR		-		5
TOTAL	600	58	÷	10
NLG/kWh	30	29	÷	5

POWER RELATED COSTS, NLG/kW (NLG . 10^6)

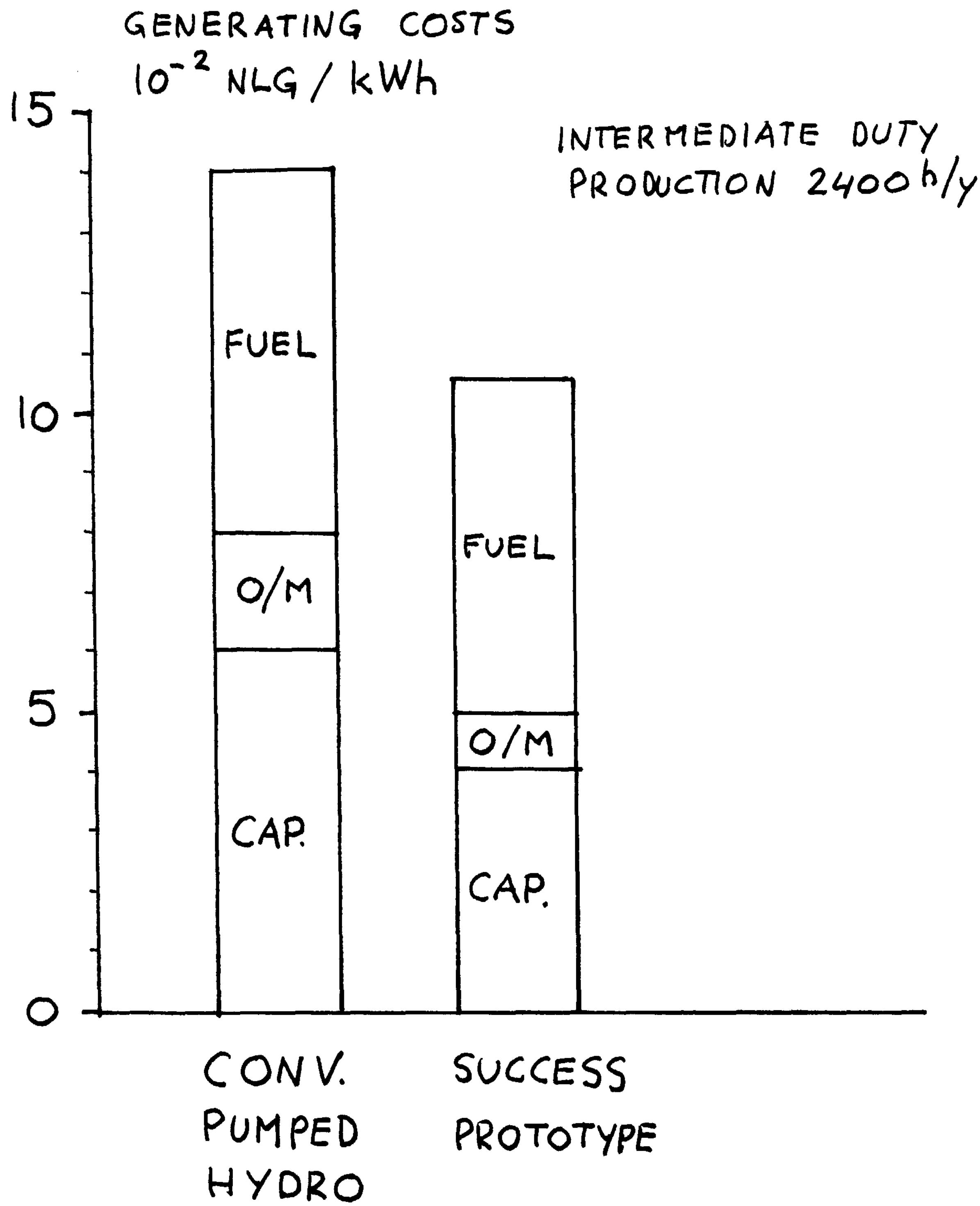
	CONV. PUMPED HYDRO, 1800 MW	SUCCESS PROTOTYPE, 110 MW	
SITE PREPARATION	~ 200	70	(8)
ELECTRICAL FACILITIES	330	330	(36)
POWER ENGINE	~ 270	220	(24)
FLUID TRANSFER TUBING	~ 400	240	(26)
TOTAL	≈ 1200	860	(94)

ROUNDTRIP LOSSES, % OF INPUT

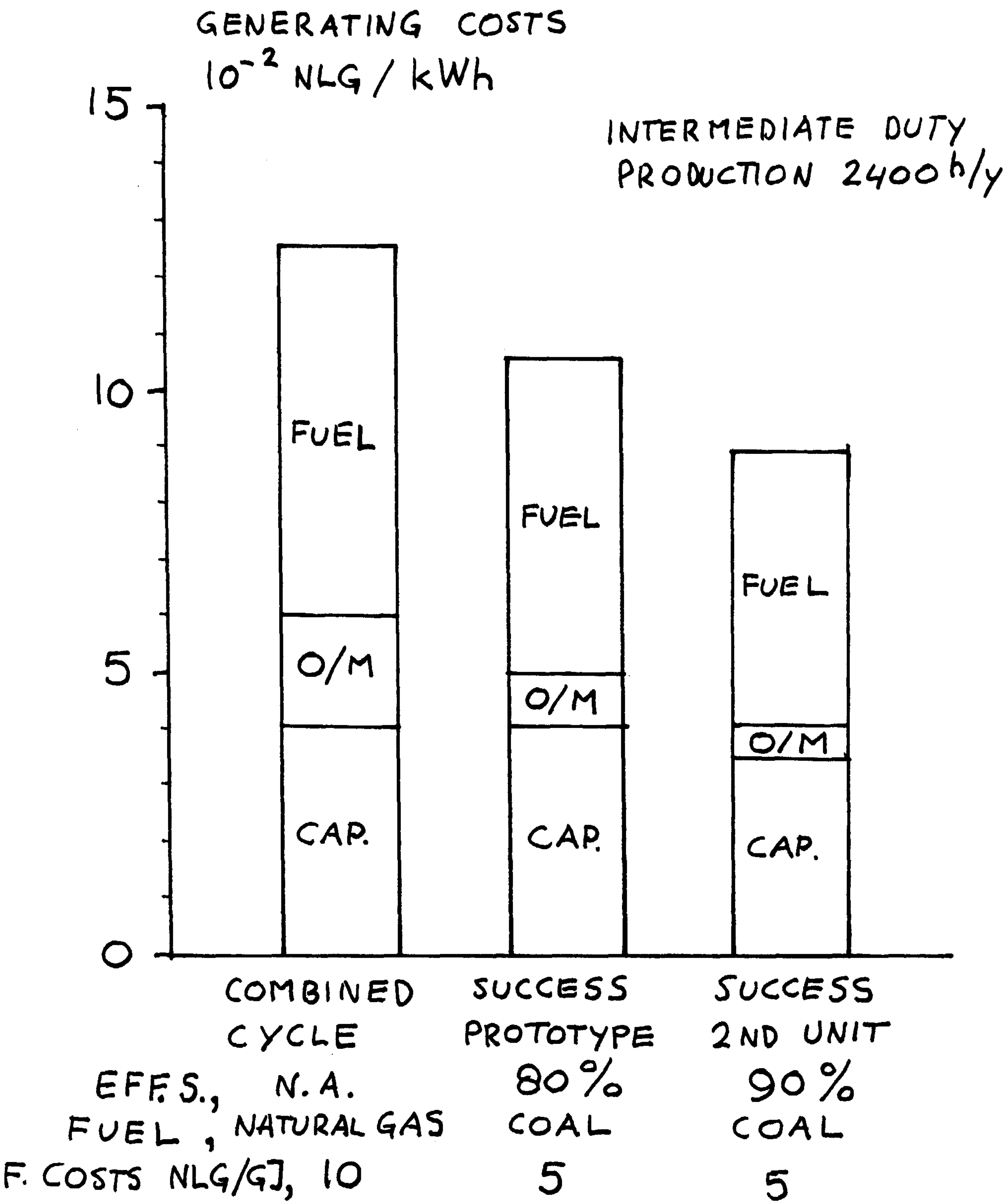
	CONV. PUMPED HYDRO	SUCCESS STATE-OF-ART PROTOTYPE	SUCCESS 2ND FURTHER OPTIMIZED UNIT
MOTOR/GENERATOR	2.0	2.0	2.0 ÷ 1.5
ENGINE MOVING PARTS	2.0	8.0	5.0 ÷ 3.0
ENGINE FLUID FLOW LOSS	17.0	4.5	2.5 ÷ 1.0
TRANSFER TUBING FLUID FLOW LOSS	1.0	5.0	5.0 ÷ 1.0
NON-ADIABATIC UNDERGROUND HEAT LOSS	N.A.	0.5	0.5
TOTAL	22	20	15 ÷ 7
ROUNDTRIP EFFICIENCY	78	80	85 ÷ 93



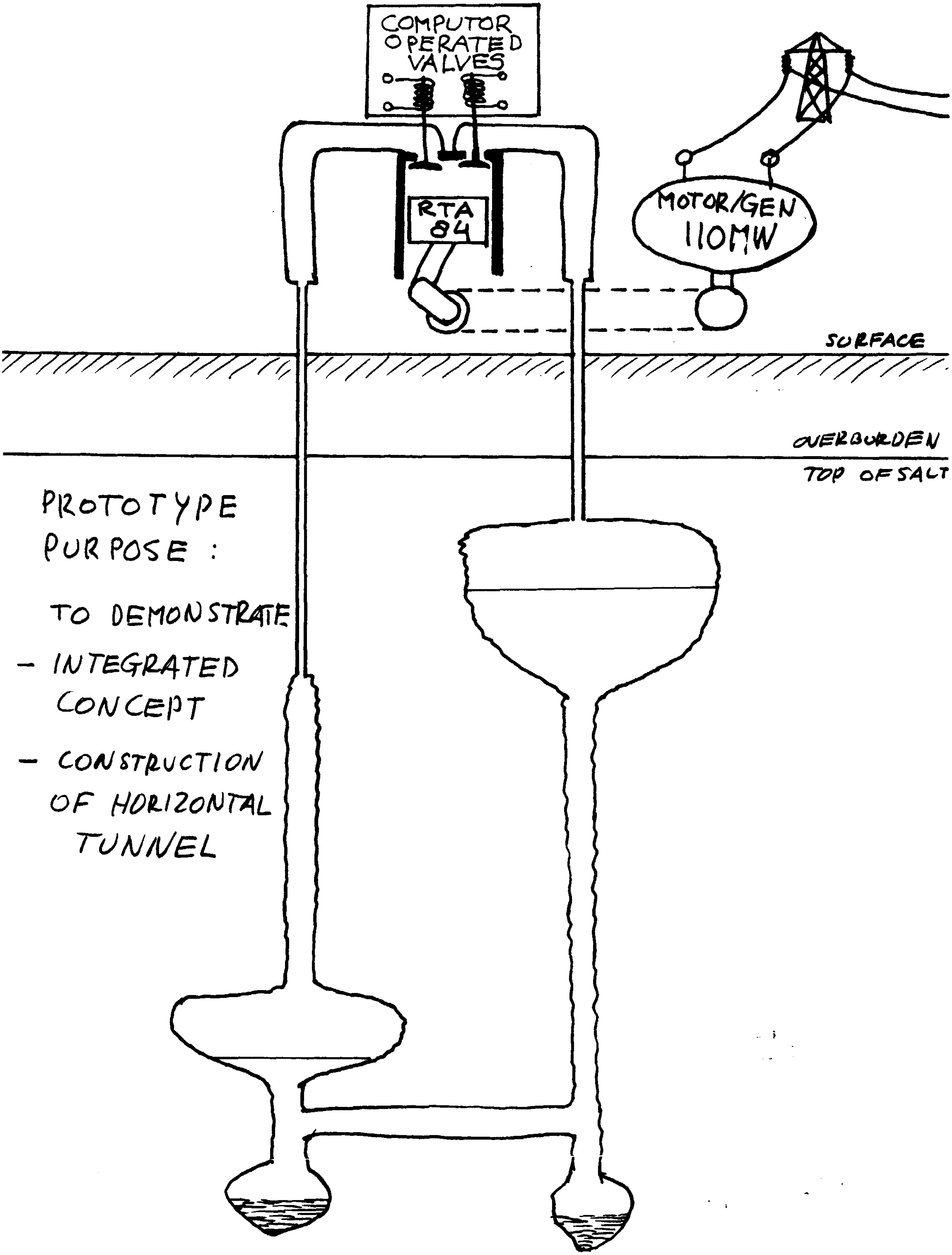
COSTS PER ITEM IN NLG 10^6
COMPUTOR OPERATED VALVES
POWER ENGINE 24
RTA 84
MOTOR/GEN 110MW
ELECTRICAL + SITE 44
SURFACE
OVERBURDEN
TOP OF SALT
FLUID TRANSFER TUBING 26
CAVERNS PROPER 31
NATURAL GAS INVENTORY 22
SHAFT TUNNEL 5
TOTAL PROTOTYPE 152
NEXT 130



COMPARISON PUMPED HYDRO vs. SUCCESS



COMPARISON COMBINED CYCLE VS. SUCCESS



PROTOTYPE PURPOSE :

TO DEMONSTRATE

- INTEGRATED CONCEPT
- CONSTRUCTION OF HORIZONTAL TUNNEL

CONCLUSIONS

1 SUCCESS, DESIGNED FOR STORAGE OF ENERGY, TURNS-OUT TO BE A HIGHLY COMPETITIVE INTERMEDIATE POWER GENERATION UNIT BECAUSE MUCH CHEAPER FUELS LIKE COAL AND URANIUM ARE USED RATHER THAN N.G.

2 IN ADDITION IT PROVIDES STORAGE FOR :
- OFF - PEAK ELECTRICITY
- POWER FROM FLUCTUATING SOURCES LIKE WIND, WATER, SOLAR ETC.
- NATURAL GAS FOR PEAK DEMAND ON EXTREMELY COLD WINTER DAYS.

3 IN ADDITION THE "IDLE" HOURS (4000/Y) OF THE POWER ENGINE CAN BE USED FOR COMPRESSION OF NATURAL GAS INTO WORKED-OUT GAS RESERVOIRS OR AQUIFIERS FOR SEASONAL STORAGE.