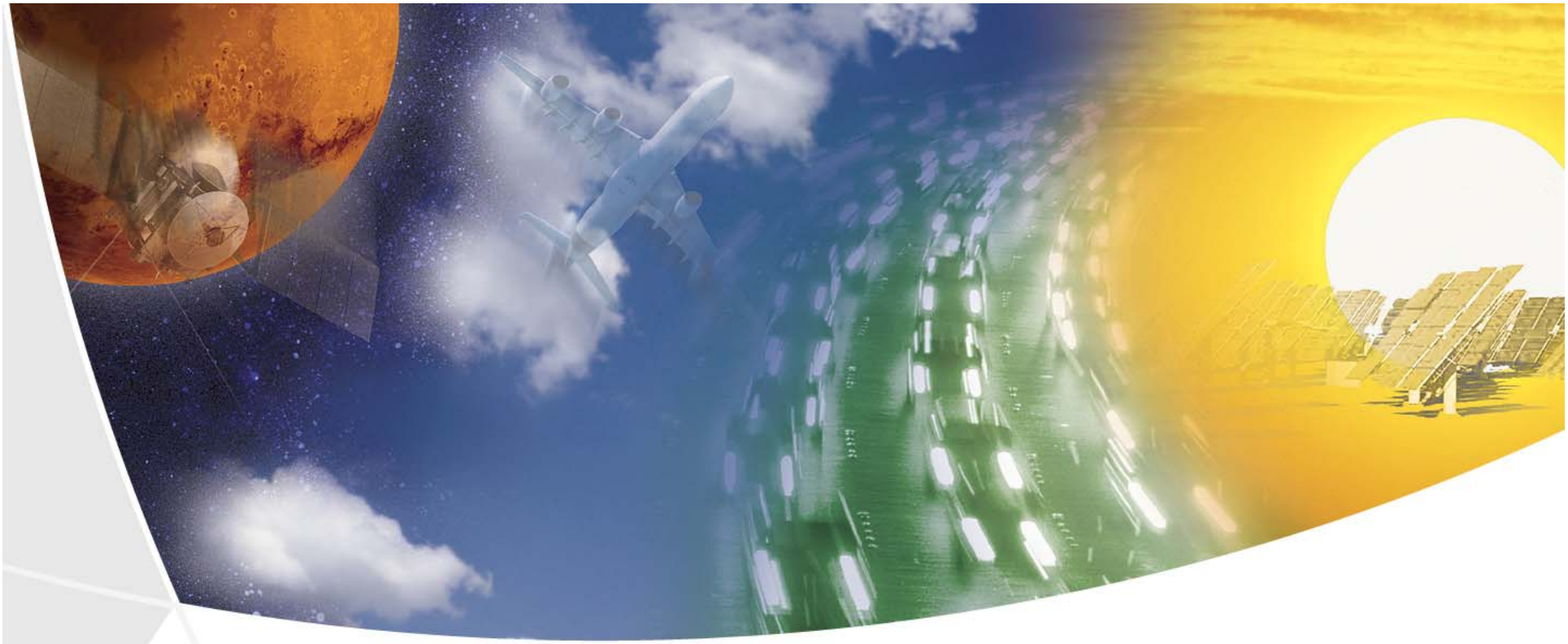

Development of Operating Buildings, PV-Electrolysis Facilities & Safety Technology

German-Saudi Arabian Joint Project HYSOLAR (HYdrogen from SOLAR Energy) 1986 – 1995

Visit of a Delegation of the King Faisal University of Dammam, Kingdom of Saudi Arabia, on July 9th, 2010

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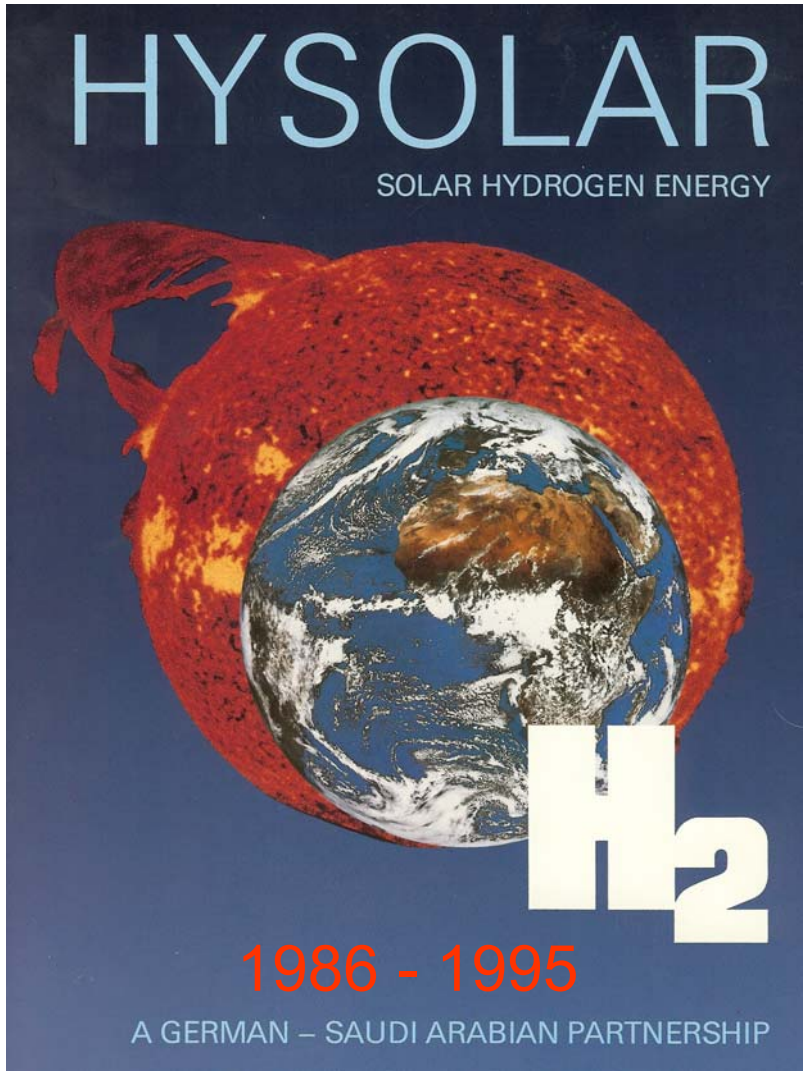
DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Contents of the Presentation

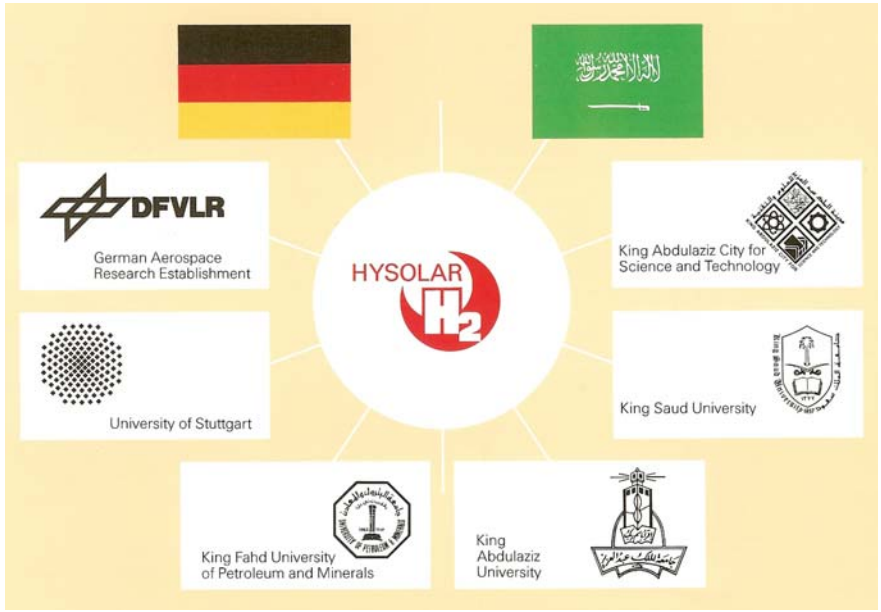
- Short introduction to the HYSOLAR project
- Test- and production demonstration facilities
- Conceptual system and electrolysis block variants
- Experimental and regular operation
- Important results
- Improvement potentials

Project Hysolar: Mission & Partners



برنامج إنتاج الهيدروجين بالطاقة الشمسية
هايسولار

SOLAR HYDROGEN PRODUCTION AND UTILIZATION
A COOPERATION IN RESEARCH, TECHNOLOGY AND EDUCATION



برنامج سعودي ألماني مشترك

Project Financing & Working Packages

HYSOLAR

FEDERAL REPUBLIC OF GERMANY

and the

KINGDOM OF SAUDI ARABIA

funded by

King Abdulaziz City for Science and Technology (KACST)

Bundesminister für Forschung und Technologie (BMFT)

Ministerium für Wissenschaft und Kunst des Landes Baden–Württemberg (MWK)

Design, installation and operation of a

Task 1
350 kW demonstration plant

Task 2
10 kW test and research facility

Task 3
2 kW test and research facility

Accomplishment of a

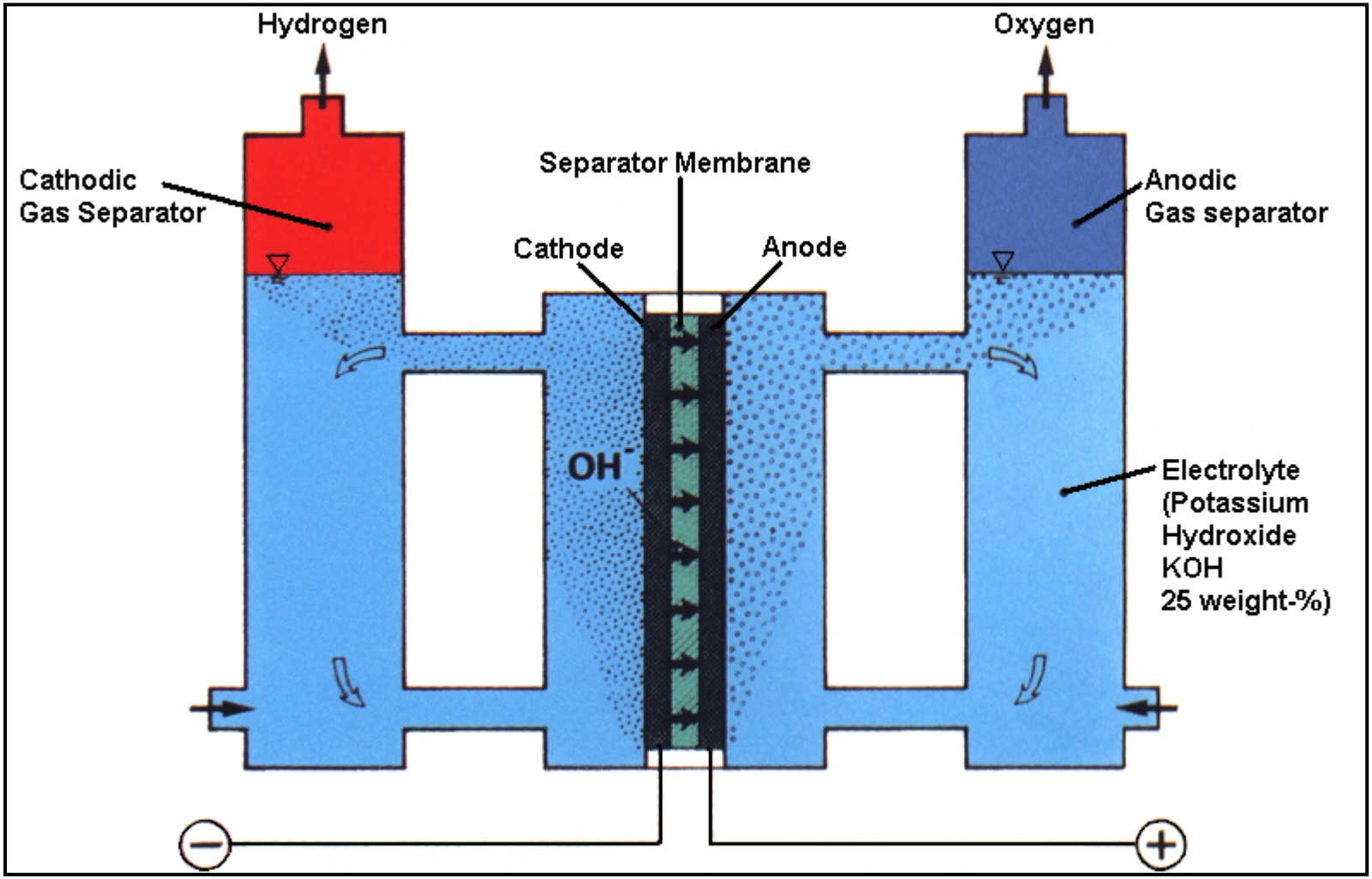
Task 4
Fundamental research programme

Task 5
System studies and utilization programme

Task 6
Educational and training programme

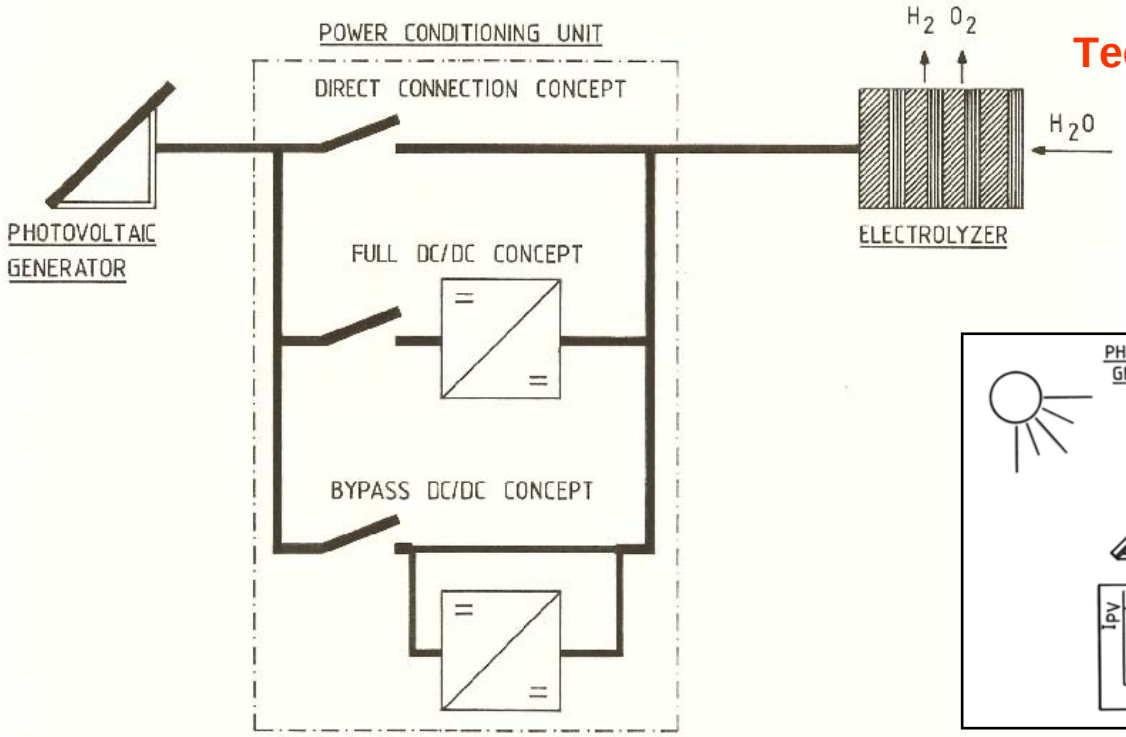
With this programme the project HYSOLAR is starting from a safe basis guaranteeing relevance for near term applications and clearing the ground for the long term research on solar hydrogen.

Functional Principle of an Alkaline Electrolysis Cell



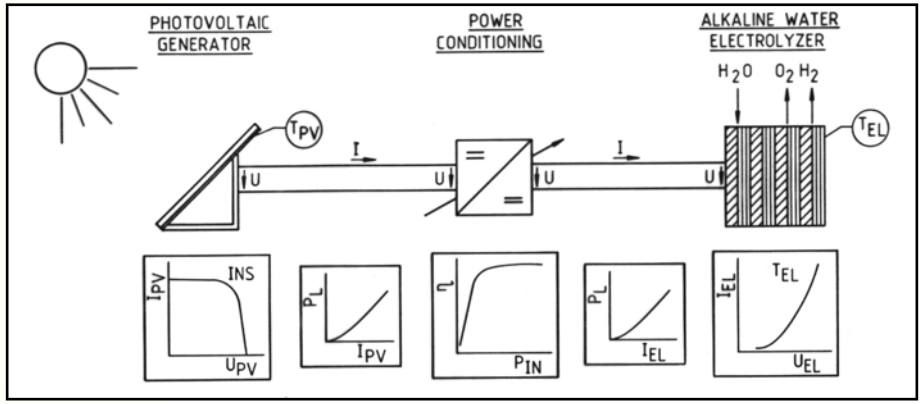
Coupling of energy converters

- Development and use of a test and data evaluation standard
- Long-term examination of coupling behaviour of a PV-electrolysis system



Technical Principle

Functional Principle



Experimental system setup in the HYSOLAR project

Examination and evaluation of different coupling principles between photovoltaics and electrolysis

PV-Electrolysis-Plants of the Project

RIYADH

350/500kW Solar-hydrogen

production demonstration plant

Demonstration operation

1993 - 2000

STUTTGART

10kW Solar hydrogen

research and development facility

Experimental operation

1987 - 2004

JEDDAH

3kW Solar hydrogen

test facility

Test operation

1989 - 1995

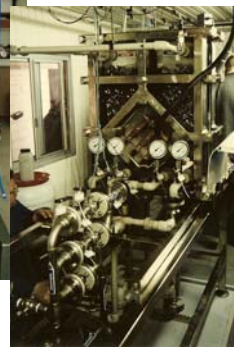
Electrolysis Facilities of the Project

P = 2 – 350/ 500kW, p = 1 -10bar$_{abs}$, T = 40 – 95°C

(1) Research/ Test systems

HT

HT/DLR



HT/ DLR

Original Deliverer

HYDROTECHNIK

3 / 2kW

HS

HS/DLR

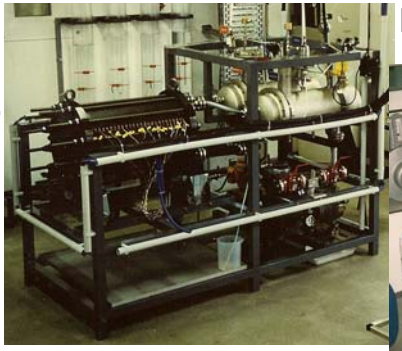
Original Deliverer

HYDROGEN SYSTEMS /

METKON ALYZER 10kW

MA

MA/DLR



FZJ

FZJ/DLR

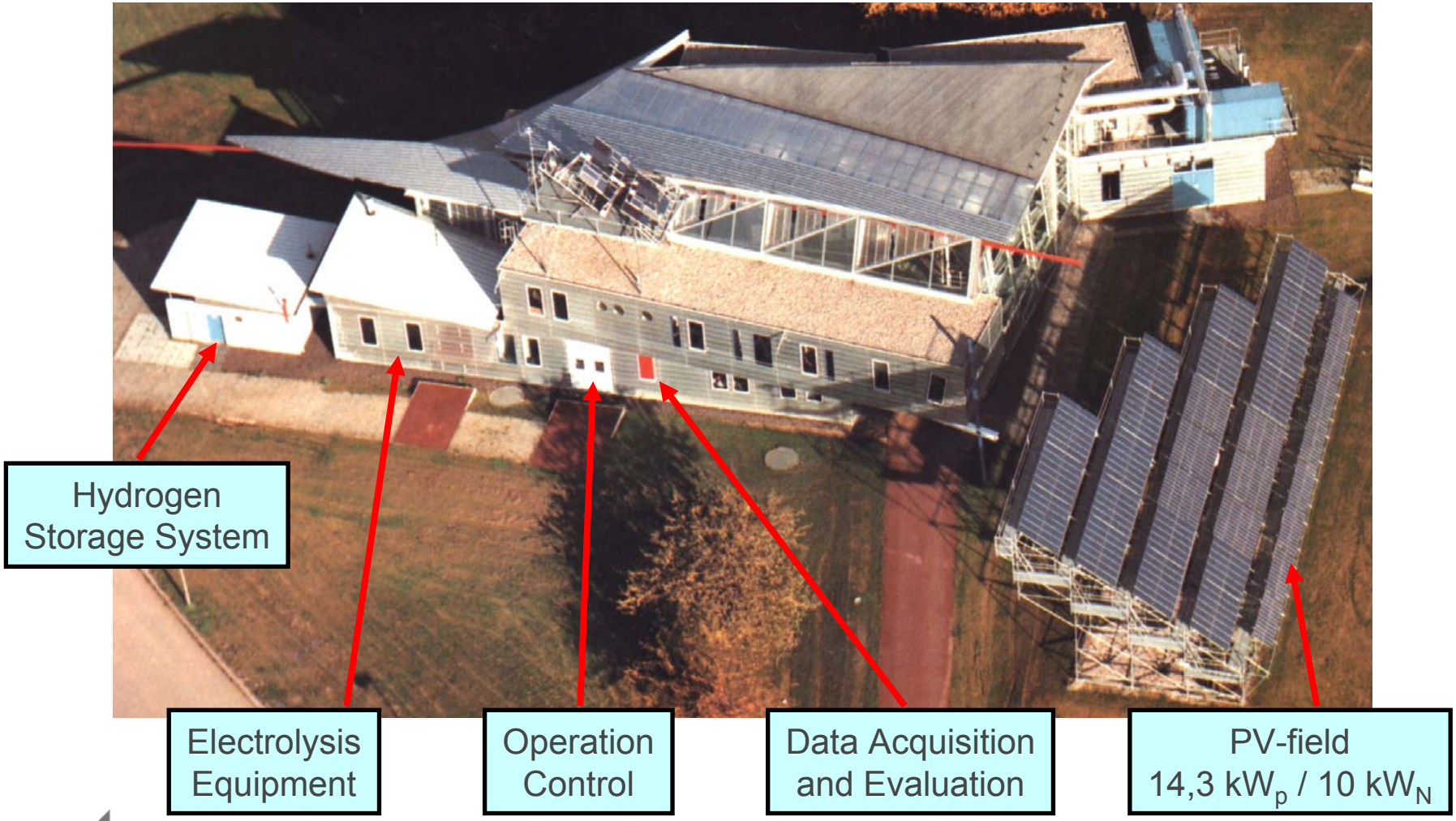
Original Deliverer

FZ JÜLICH

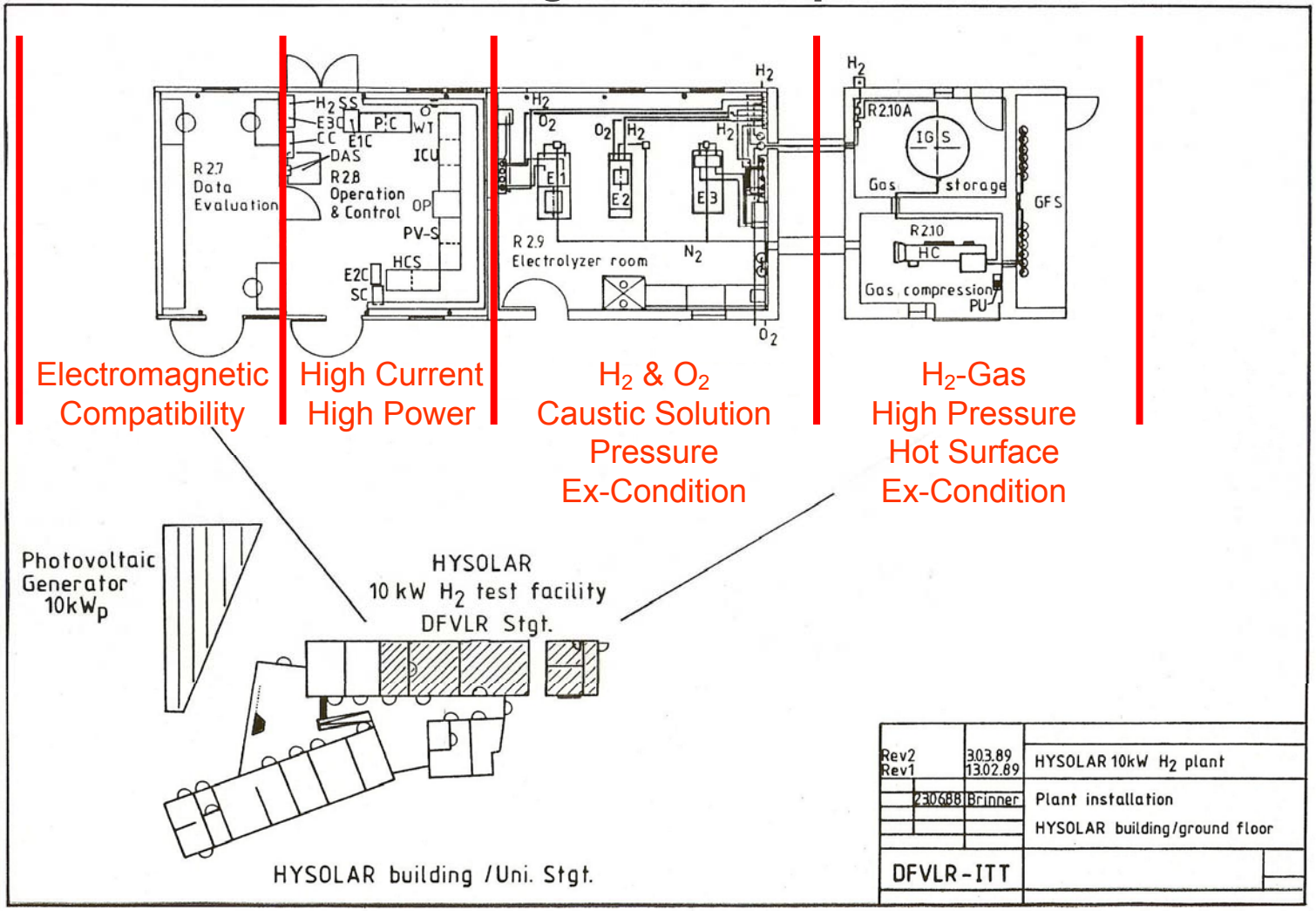
10kW

FZJ/DLR

10 kW_N Photovoltaic-Electrolysis Facility in the HYSOLAR Building



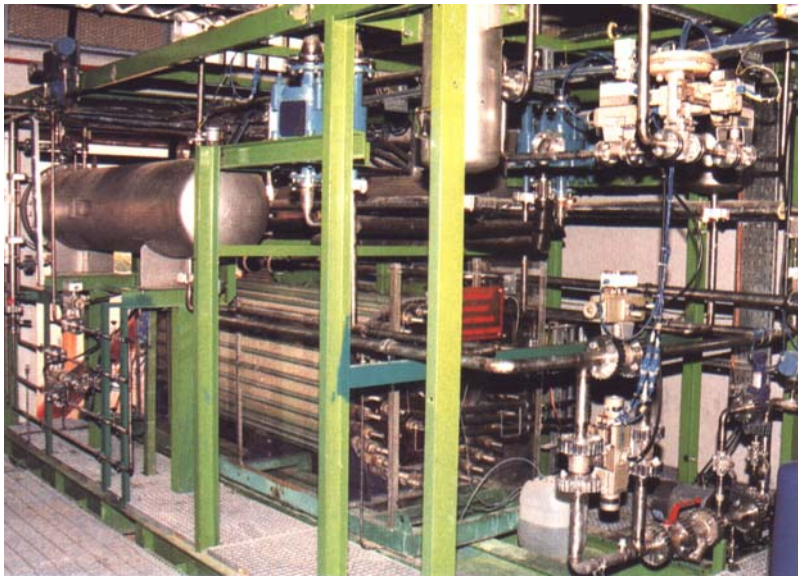
10 kW_N Photovoltaic-Electrolysis Facility in the HYSOLAR Building, Main Requirements for Concept



Electrolysis Plant of the Project

P = 2 – 350/ 500kW, p = 1 -10bar$_{abs}$, T = 40 – 95°C

(2) Produktion demonstration



350/500 kW pressure electrolysis plant approved by TUEV, in operating condition

5000cm²- block V.1

Not accepted

5000cm²- Block V.2

Not accepted

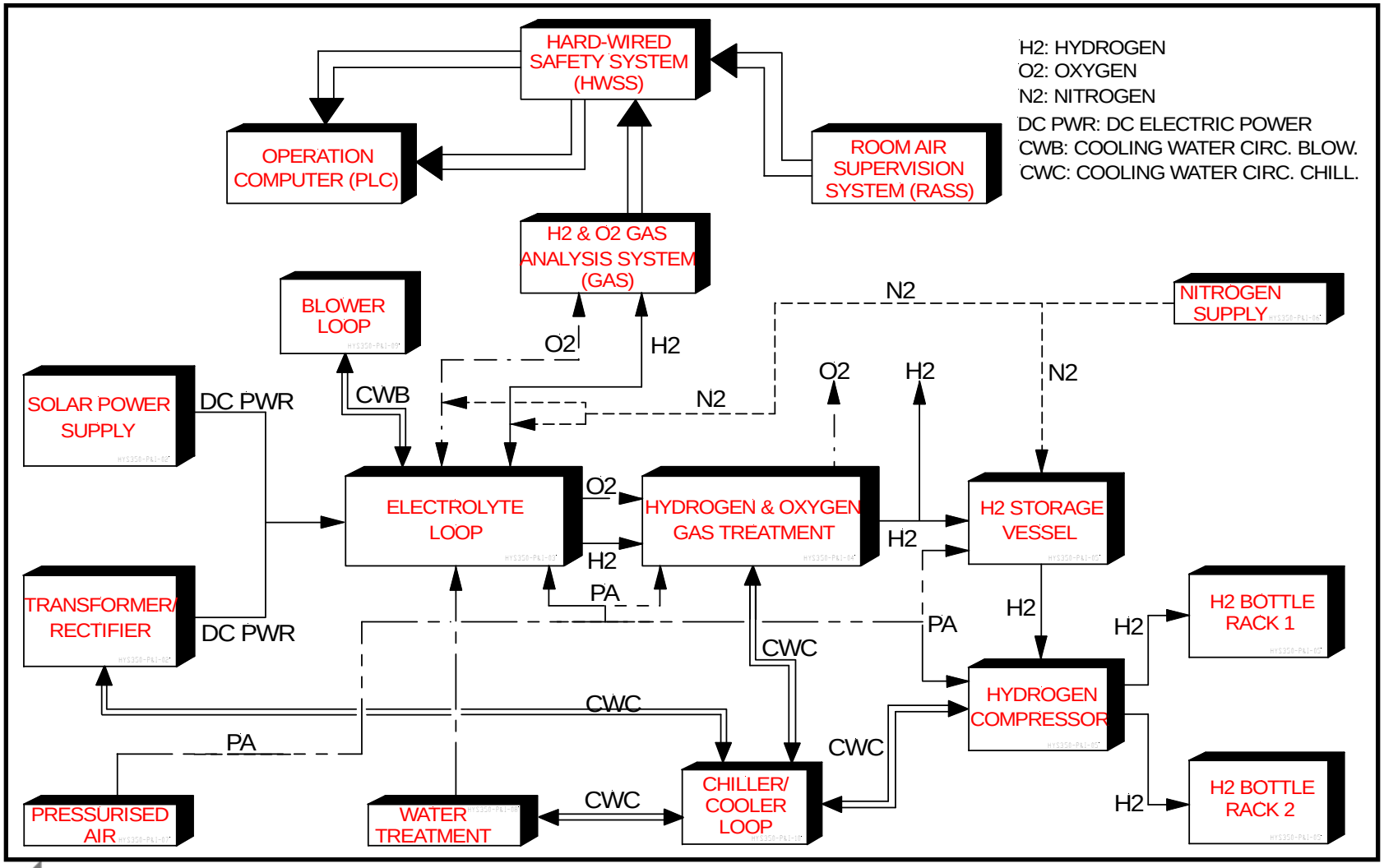
2500cm²- Block V.3

Accepted and approved

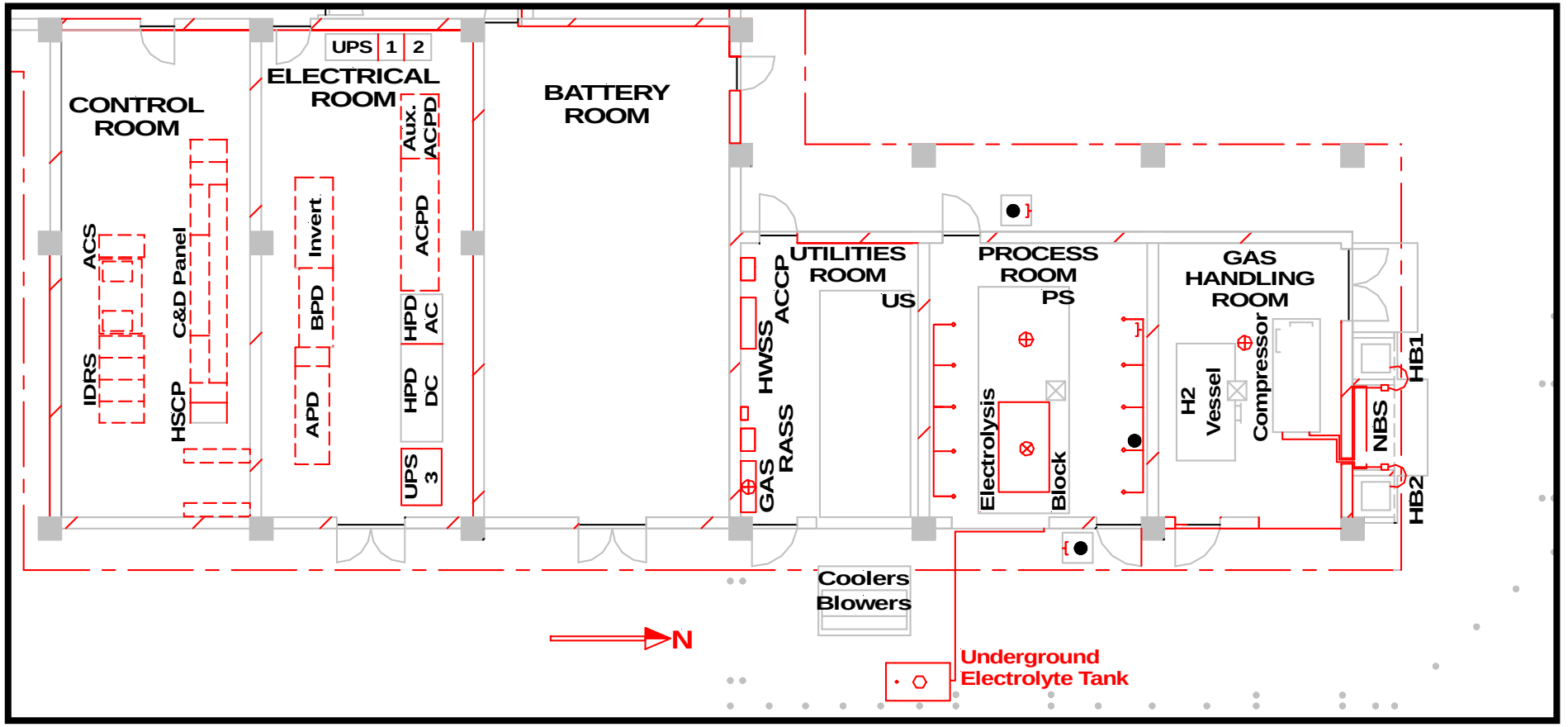
350 kW_p PV-Field of KACST in Riyadh for H_2-Production

Facility Building of the 350 kW_p Photovoltaic Elektrolysis Plant

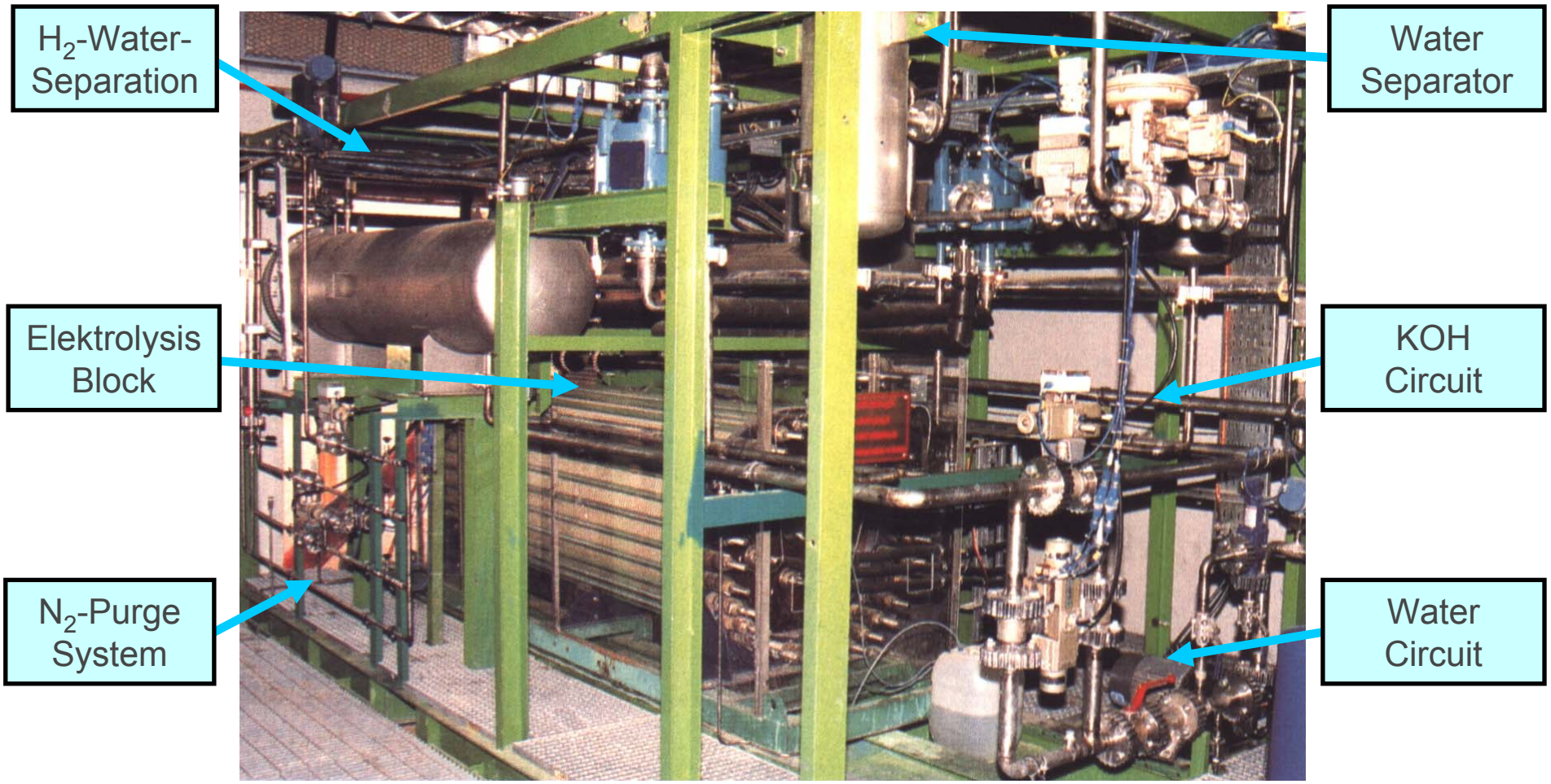
Block Diagram of the 350 kW PV-Electrolysis Plant



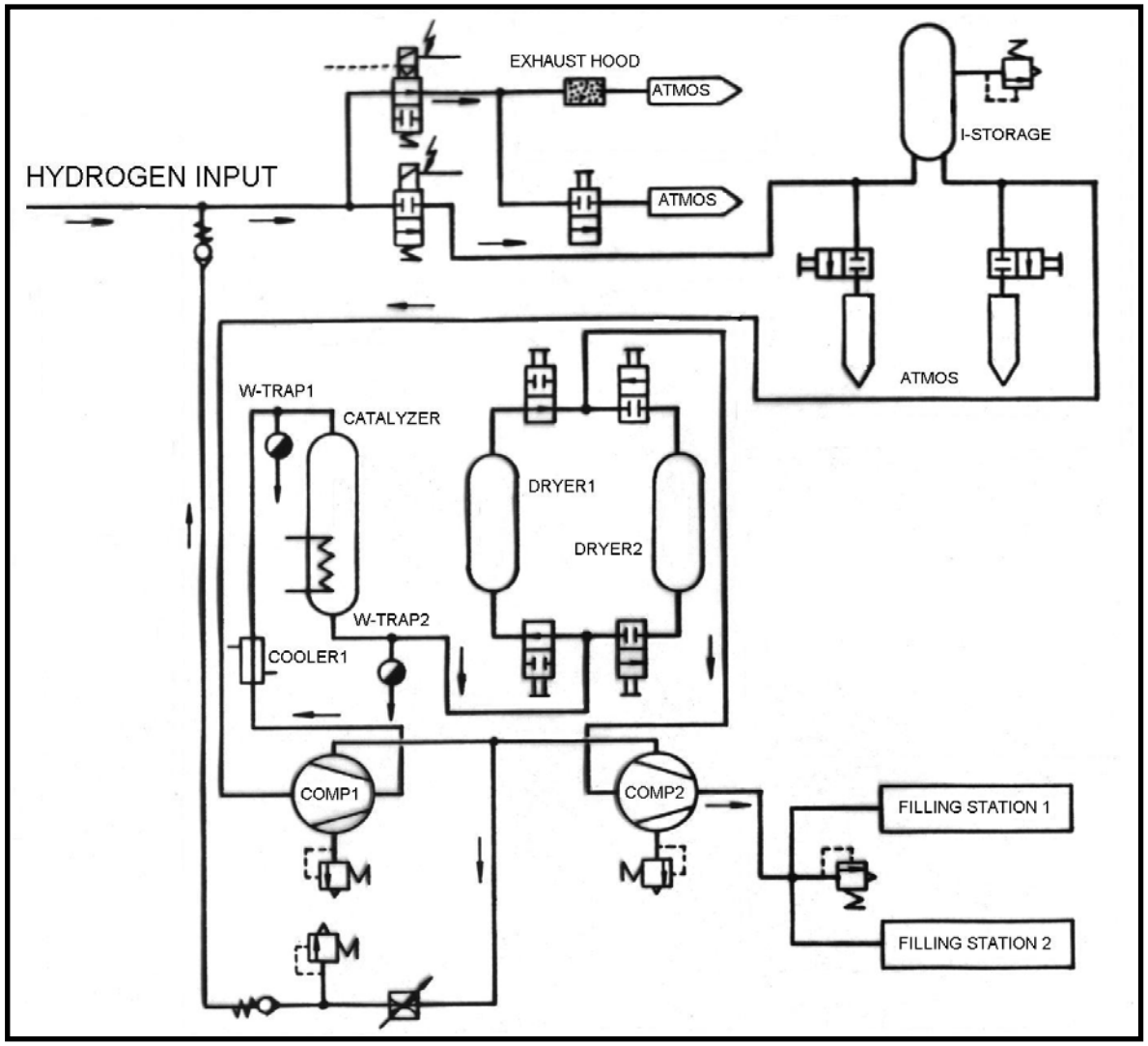
System Installation of the 350 kW_p PV-Electrolysis Facility



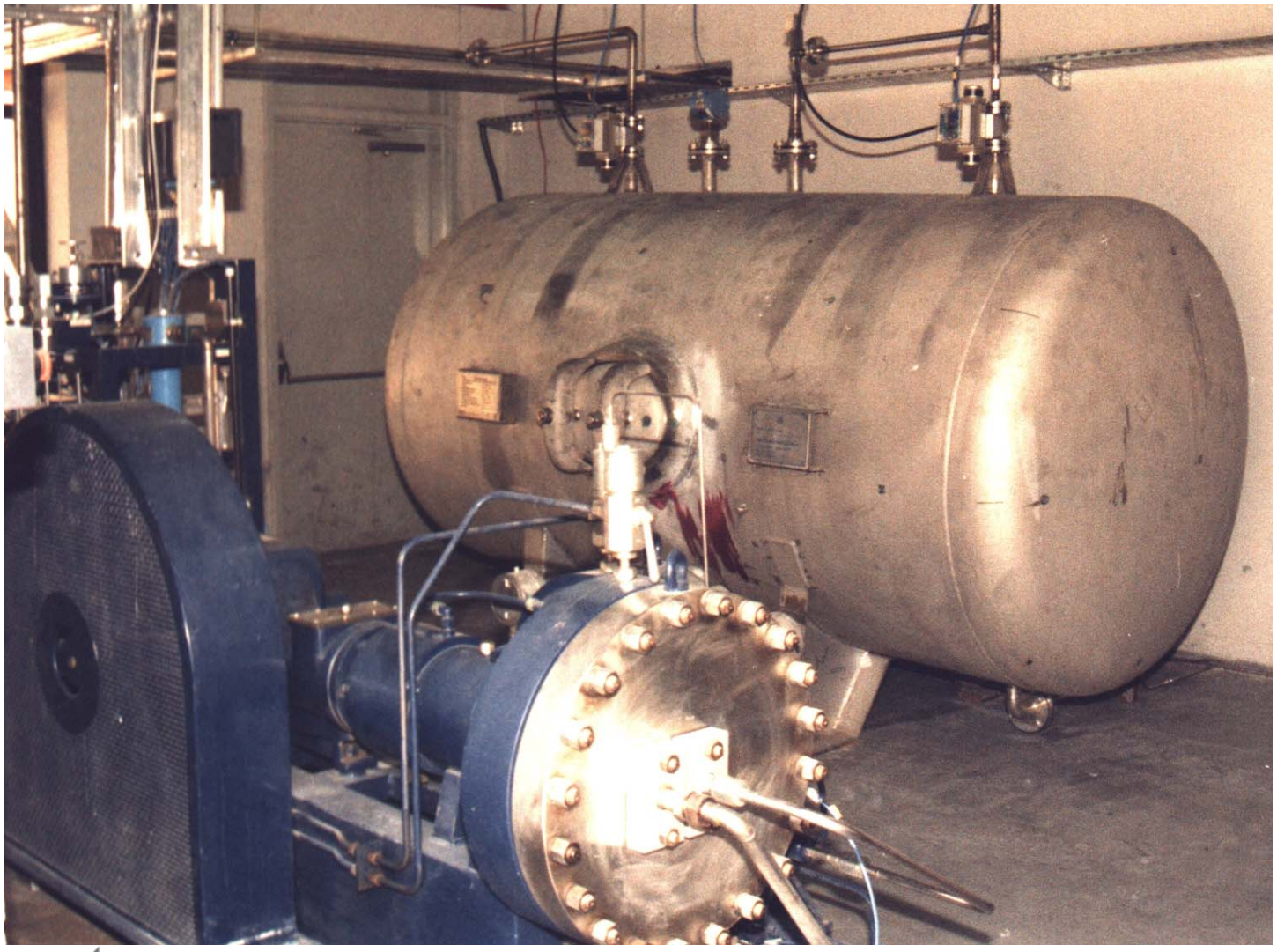
Alkaline 0,5 MW_N Pressure Electrolyser



Dynamically Operated H_2-Purification and Storage System



H_2-Purification and Storage System of the 350 kW Facility

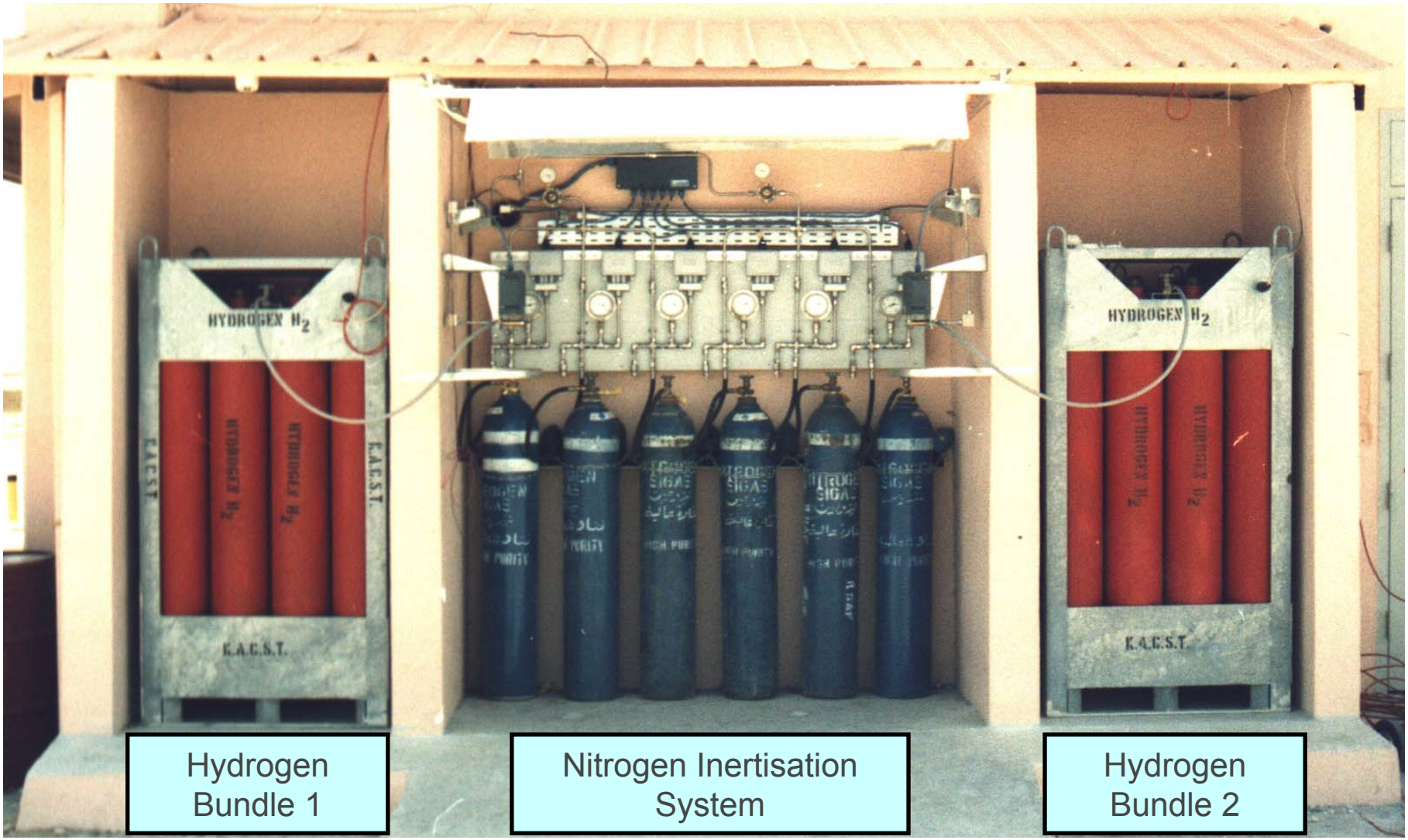


Intermediate Storage
40 Nm^3 Content
at 9 bar_{abs}

Purification System
from Quality
99.9 to 99.999

Hydrogen Compressor
65 Nm^3 from
9 to 151 bar_{abs}

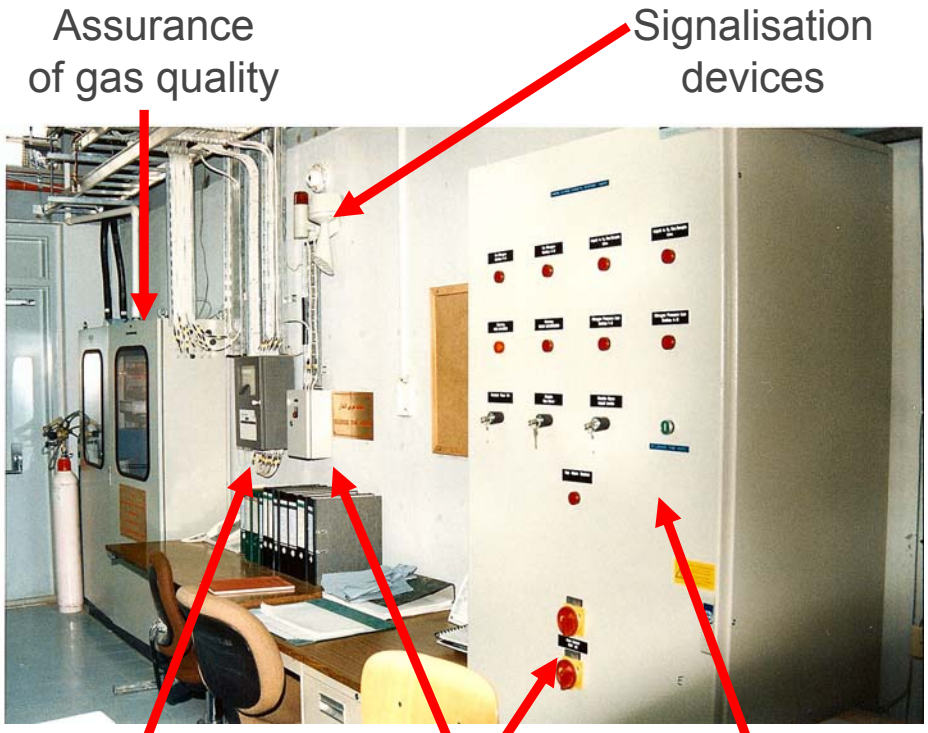
Hydrogen / Nitrogen Storage of the 350 kW Facility



Dynamic electrolysis operation is safe with actual techological state of the art and can be approved regularely

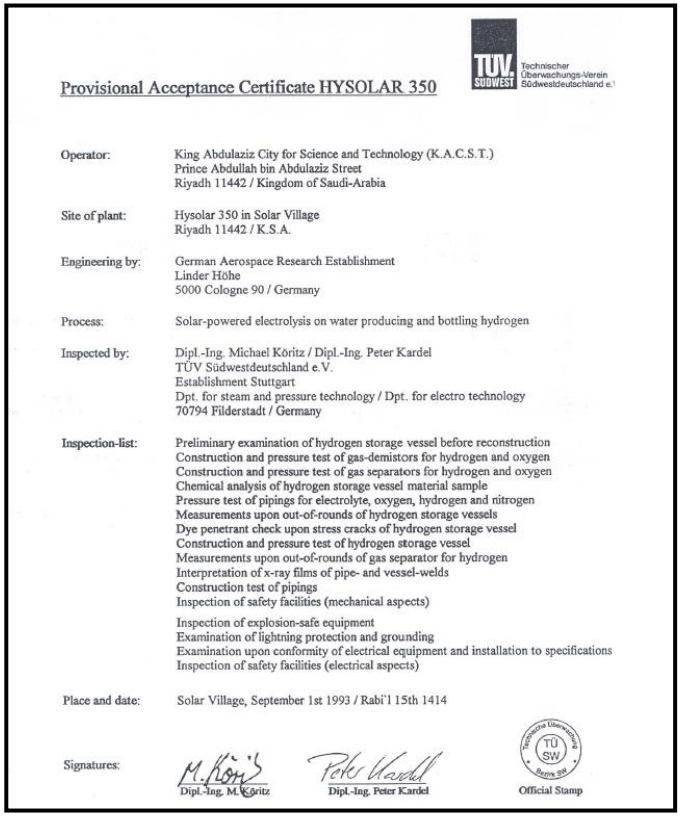
Safety technology can be standardised

for all kinds and power levels of electrolysis plant



HYS 10 & HYS 350

Operating permission for production and delivery of solar hydrogen



Provisional Acceptance Certificate HYSOLAR 350

TÜV SÜDWEST Technischer Überwachungs-Verein Südwestdeutschland e.V.

Operator:	King Abdulaziz City for Science and Technology (K.A.C.S.T.) Prince Abdullah bin Abdulaziz Street Riyadh 11442 / Kingdom of Saudi-Arabia
Site of plant:	Hysolar 350 in Solar Village Riyadh 11442 / K.S.A.
Engineering by:	German Aerospace Research Establishment Linder Höhe 5000 Cologne 90 / Germany
Process:	Solar-powered electrolysis on water producing and bottling hydrogen
Inspected by:	Dipl.-Ing. Michael Köritz / Dipl.-Ing. Peter Kardel TÜV Südwestdeutschland e.V. Establishment Stuttgart Dpt. for steam and pressure technology / Dpt. for electro technology 70794 Filderstadt / Germany
Inspection-list:	Preliminary examination of hydrogen storage vessel before reconstruction Construction and pressure test of gas-demistors for hydrogen and oxygen Construction and pressure test of gas separators for hydrogen and oxygen Chemical analysis of hydrogen storage vessel material sample Pressure test of pipings for electrolyte, oxygen, hydrogen and nitrogen Measurements upon out-of-rounds of hydrogen storage vessels Dye penetrant check upon stress cracks of hydrogen storage vessel Construction and pressure test of hydrogen storage vessel Measurements upon out-of-rounds of gas separator for hydrogen Interpretation of x-ray films of pipe- and vessel-welds Construction test of pipings Inspection of safety facilities (mechanical aspects) Inspection of explosion-safe equipment Examination of lightning protection and grounding Examination upon conformity of electrical equipment and installation to specifications Inspection of safety facilities (electrical aspects)
Place and date:	Solar Village, September 1st 1993 / Rabi`l 15th 1414
Signatures:	Dipl.-Ing. M. Köritz Dipl.-Ing. Peter Kardel Official Stamp

Improvement potentials

► **EFFICIENCY**	Improved materials für membranes and cell frames
► **COSTS**	Simplification of system peripherals
► **OPERATING RANGE**	Increase of product gas quality in dynamic operation
► **OPERATING RANGE**	Improvement of tolerance to user lower water qualities
► **AUTONOMITY**	Grid autonomy of the entire system
► **OPERATING COSTS**	Automation of dynamic operation
► **AVAILABILITY**	Industrialisation of development results

What is left to be done? A LOT!!!

Thank you very much for your attention !