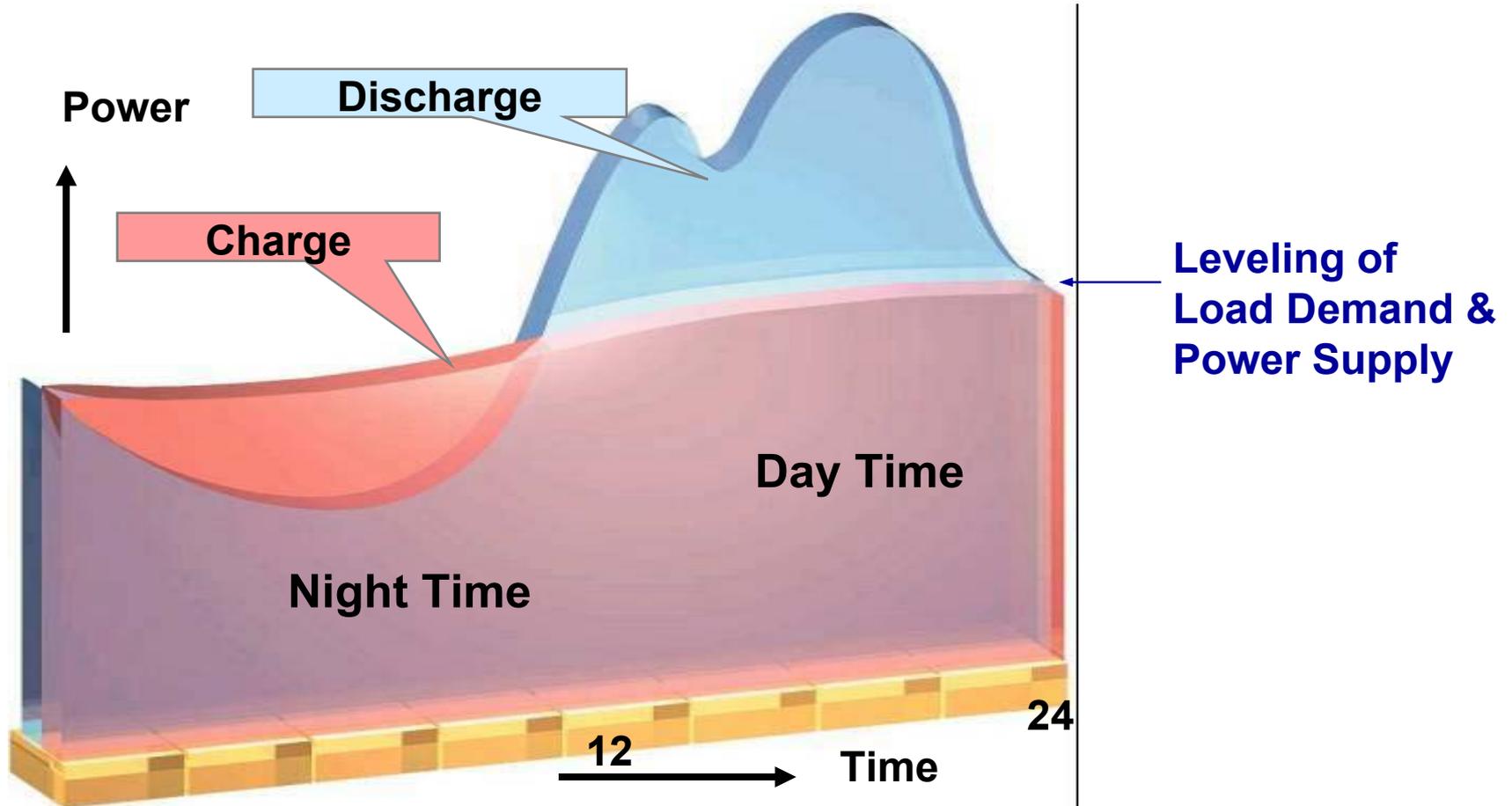

Overview of NAS Battery for Load Management



**CEC Energy Storage Workshop
February 2005**

Load Management with Energy Storage



NAS Battery Highlights

- **Mid 1980s - TEPCO/NGK commence joint R&D**
- **Late 1980s – NGK/ABB commence cooperative exchange**
- **1992 – First demo project at TEPCO – still operating**
- **April 2002 – Over 50 demo projects later, NAS systems offered commercially in Japan**
 - **TEPCO offers commercial systems within its service area; since followed by other major utilities**
 - **NGK offers integrated commercial systems via teaming with Toshiba plus other PCS vendors**
- **September 2002 – AEP hosts first U.S. demonstration project**
 - **Power electronics/system integration provided by ABB**
 - **Other projects under development in U.S., Europe and SE Asia**
- **April 2003 – NGK initiates commercial scale NAS manufacturing**
 - **40 MW produced in 2003, ~65 MW in 2004**
 - **Space and plans for near-term expansion to ~140 MW/yr**
- **July 2004 – Operation of largest new NAS installation to date**
 - **9.6 MW/57.6 MWh project by TEPCO for Hitachi’s auto systems factory**

July 2004 – Hitachinaka, Japan

New NAS Battery Facility for Hitachi

The World's Largest Battery System for Energy Storage is now Operational at Hitachi's Automotive Systems Factory in Japan.



4 x 40 G50 Module Units
9.6 MW, 57.6 MWh for
Daily Load Shifting
51.2m (L) x 22.6m(W) x 5.2m(H)
= 1160m² Footprint

April 2003 – Nagoya/Komaki, Japan New NAS Battery Manufacturing Plant

NAS Battery Goes Commercial in Japan

New Firing Kiln
In Nagoya

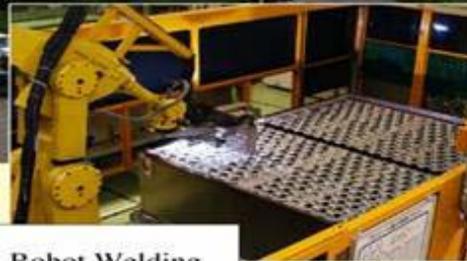


Beta Alumina -
Alpha Alumina Bonding



Komaki Plant

Production Capacity : 65MW/Yr.
6000 sq.m Factory + 1000 sq.m Warehouse
Land Space for 200MW is Available for
Future Expansion

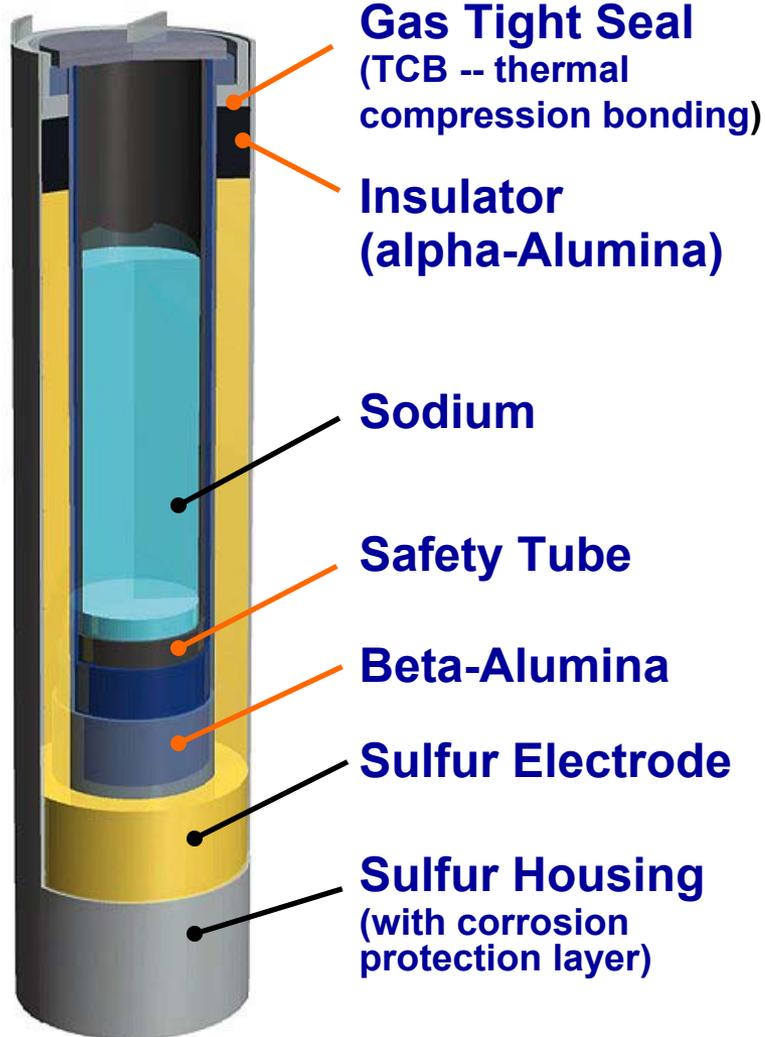


Robot Welding



500kW NAS

Structure of NAS Battery Cell



- **Low resistance, high efficiency due to**
 - Beta Alumina tube
 - Sulfur electrode design

- **High durability due to**
 - Corrosion protection layer
 - Sulfur electrode design

- **High energy density due to**
 - Cell properties and design

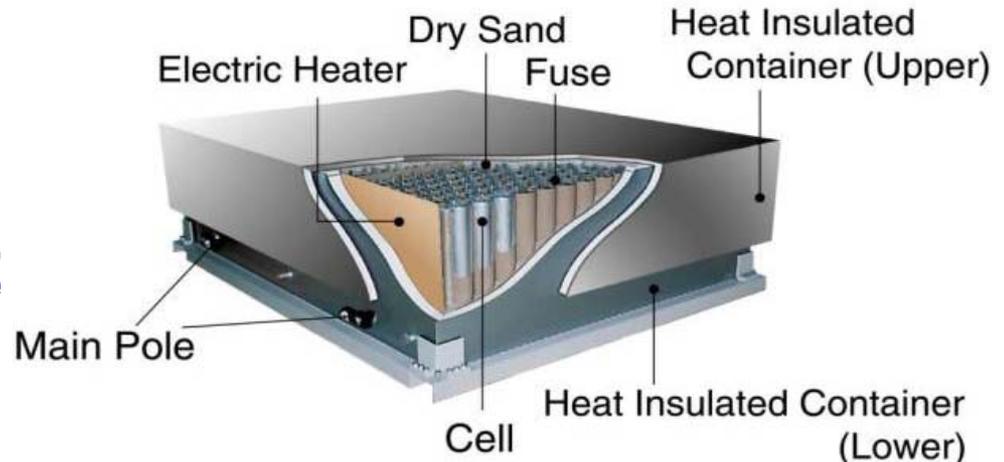
- **Intrinsic safety due to**
 - Incorporation of safety tube

NAS Technology: Battery Module Overview

- **Battery module: cells connected in series/parallel or series arrays within a thermally insulated enclosure**
 - Nominal AC capacity: 50 kW, 360 or 430 kWh (320 or 384 cells)
 - Operating temperature range: 290 and 360C
 - 3500 kg; L x W x H = 2.3 x 1.7 x 0.7 = 2.9 m³
 - Modules configured in series and/or parallel to support multi-megawatt loads

- **Protective measures:**

- Safety tube incorporated in cell design
- Hermetically sealed cells
- Double-layer stainless steel, vacuum insulated enclosure
- Sand filler packing between cells
- Fused electrical isolation



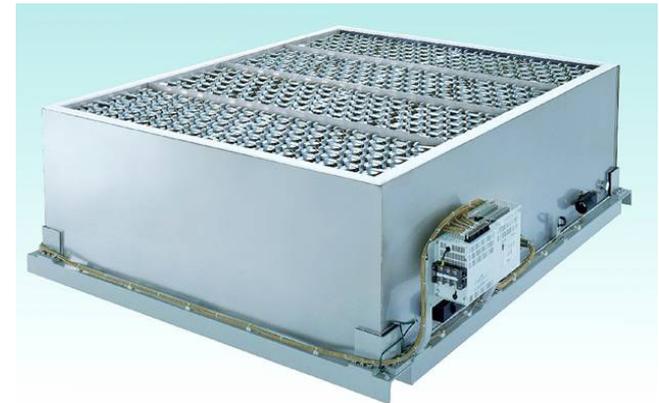
NAS Product Lines

- **NGK offers NAS battery modules in two product lines:**
 - PS Modules: Best suited for long duration discharges typical of Peak Shaving applications
 - PQ Modules: Best suited for high power, short duration discharges typical of Power Quality applications
- **PS Modules are available in two configurations**
 - PS-E50 Modules nominally rated at 50 kW, 430 kWh
 - PS-G50 Modules nominally rated at 50 kW, 360 kWh
- **PQ Modules are available in one configuration**
 - PQ-50 Modules nominally rated at 50 kW, 360 kWh, or 150 kW for 30 seconds/hr plus 360 kWh, or up to 250 kW for 30 seconds/hr

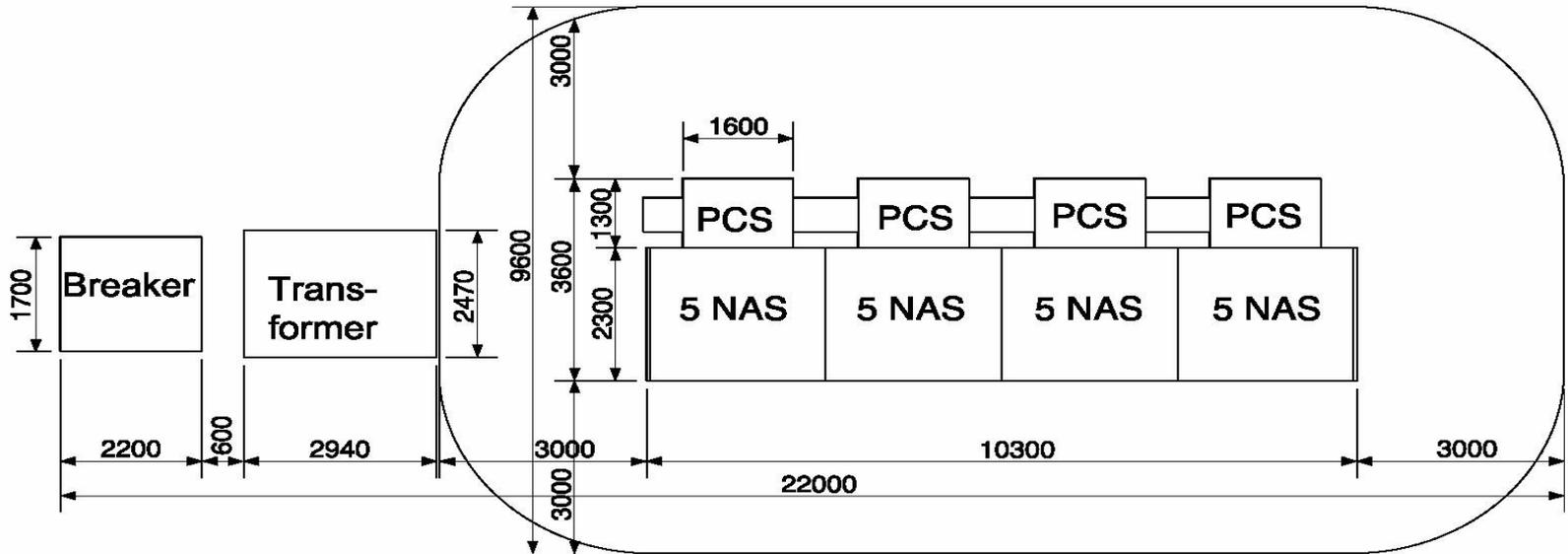
NAS Product Line: Standard PS Modules

For PS or Long Duration Standby in “Standard 5 Module Train”

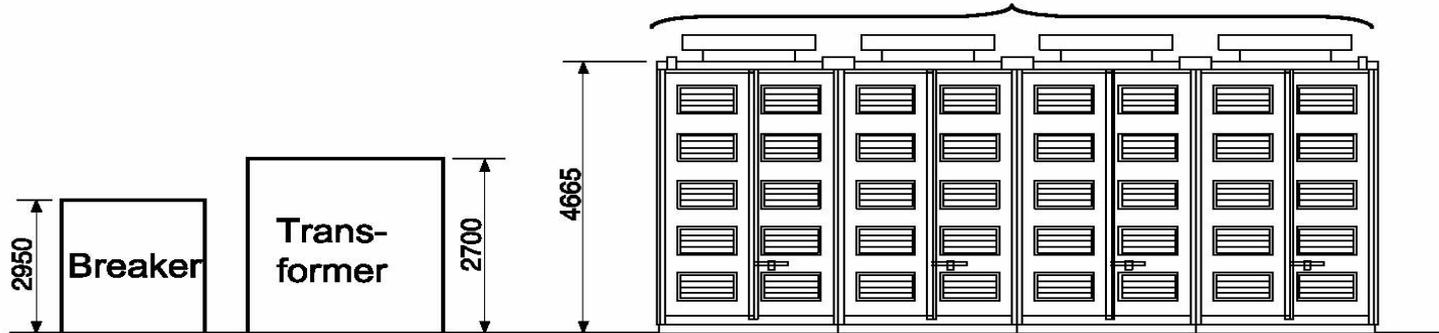
NAS Module	"PS-G50" Module	"PS-E50" Module
Module Energy Density & Avg DC Efficiency	151kWh/m ³ 85% @ 100%DOD	181kWh/m ³ 85% @ 100%DOD
Rated Capacity & Power <small>(AC, based on 95% efficiency)</small>	360kWh @ 50kW (60kW max)	430kWh @ 50kW (60kW max)
Cell Configuration & Module Voltage	(8Sx10P)x4S, 64V or (8Sx5P)x8S, 128V	(8Sx12P)x4S, 64V or (8Sx6P)x8S, 128V
Operating Temp & Standby Heat Loss	290 to 360C 3.4kW	
Dimensions (WxDxH) & Weight	2224 x 1786 x 732 mm 3500kg	
Electrical Protection	Internal fuses within each 8S string	



20 PS Module Building Block (PCS Sized for 1 or 1.2 MW)

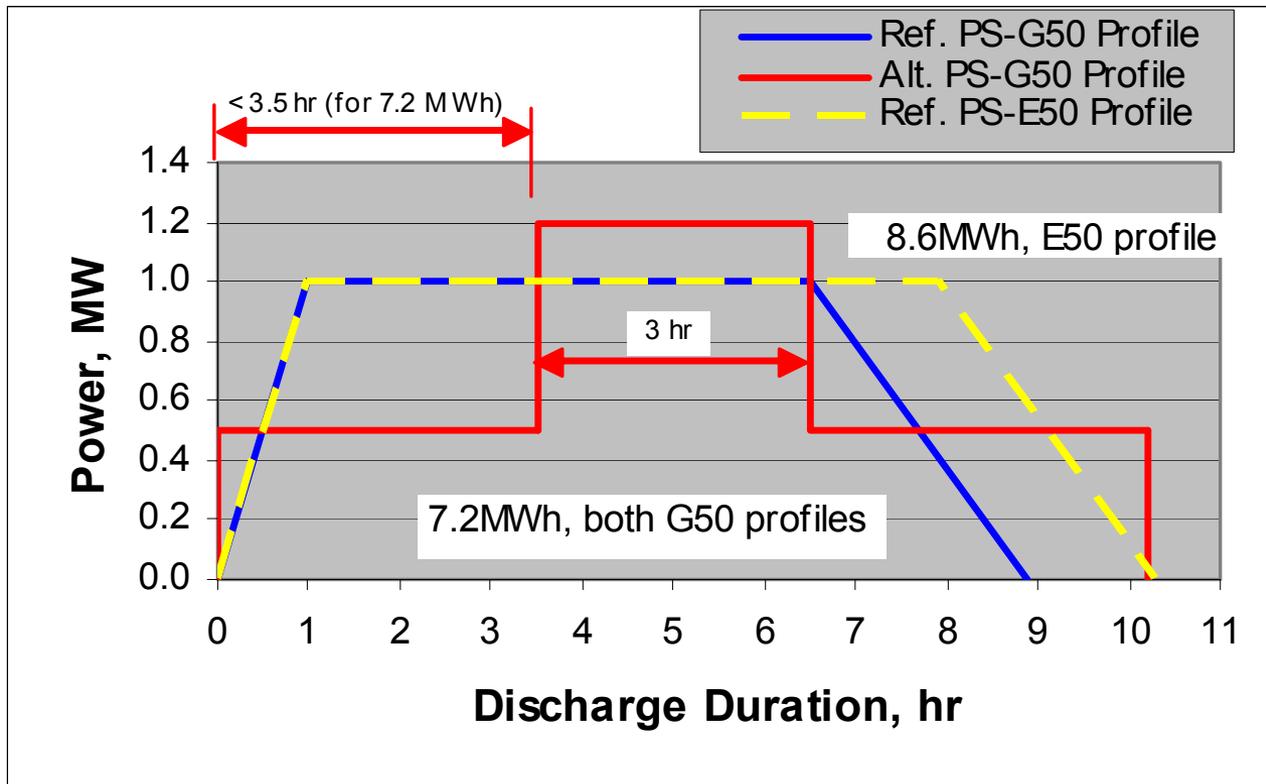


20 NAS Battery Modules



20 Module Building Block: PS Duty Cycles

20 Module Building Block PS Discharge Profiles for Rated 100% DOD per cycle (Alt PS Capable of 1.2 MW for up to 3hr with Full Discharge)

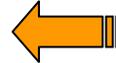


LL and PS + EPS Applications



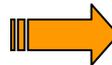
Load Leveling Application

**NAS Installation No. 18: 6MW / 48MWh
at TEPCO's Ohito Substation**



PS + EPS Application

**NAS Installation No. 49: 1.2MW / 7.2MWh
at Kasai's Sewage Disposal Plant**



NAS Product Line: Standard PQ Module

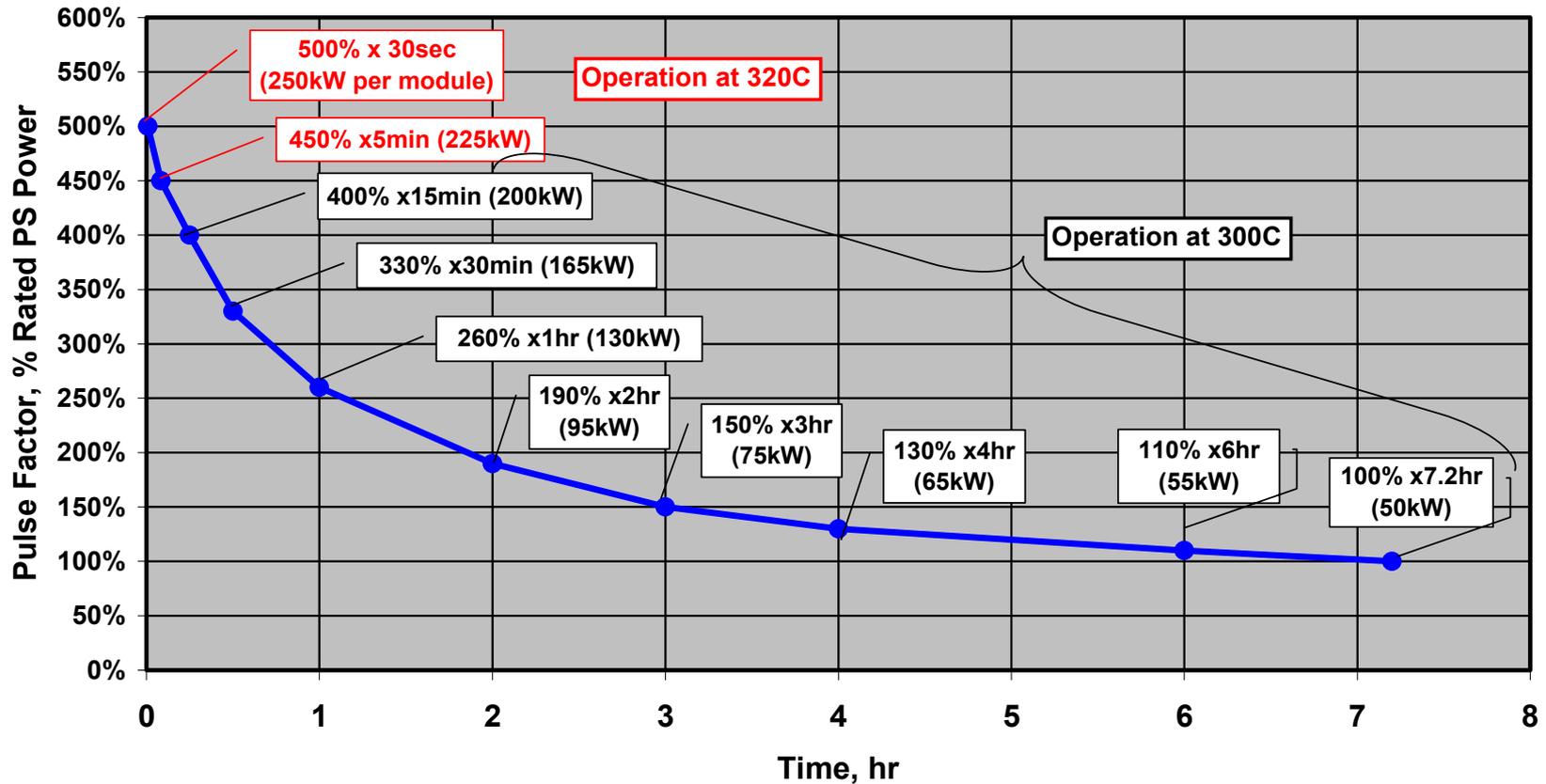
For PQ and Combined PQ & PS Applications

NAS Module	"PQ-50" Module
Module Energy Density & Avg DC Efficiency	151kWh/m ³ 85% @ 100%DOD 90% @ 40%DOD
Rated Capacity & Power <small>(AC, based on 95% efficiency)</small>	360kWh @ 50kW (250kW max)
Cell Configuration & Module Voltage	320S, 640V
Operating Temp & Standby Heat Loss	290 to 360C 2.2kW (PQ) 3.4kW (PQ & PS)
Dimensions (WxDxH) & Weight	2224 x 1786 x 732 mm 3500kg
Electrical Protection	External DC breaker, external fuse at terminal



NAS Product Line: Standard PQ Module

NAS Pulse (or "PQ Factor") vs Discharge Duration



Combined PQ & PS Applications



Large Scale PQ Application

**NAS Installation No. 57: PQ3MW / PS1MW
at Fujitsu's Akiruno Technology Center**

1st Demonstration in the USA

**NAS Installation No. 59: PQ500kW / PS100kW
at AEP's Gahanna, Ohio, Office**



Summary of Deployed NAS Projects

- **Total NAS projects deployed since 1992 through December 2004:**
 - Over 100 projects and 100 MW to date, including demonstrations
 - 59 projects >500kW have cumulative capacity of ~88MW and 680MWh (accounting for the relocation of some projects)
 - 2 projects rated at 9.6 MW and ~60 MWh – the largest battery energy storage projects in the world
- **Breakdown by market:**
 - Commercial (Comml), e.g., data handling: 29%
 - Industrial (Indl), e.g., manufacturing: 22%
 - Electric power companies (EPC), e.g., substation support: 26%
 - Water treatment plants (WTP), e.g., sewage handling: 23%
- **Breakdown by application:**
 - Load Leveling (LL): 63%
 - LL + Emergency Power Supply (EPS): 24%
 - *EPS for multi-hours of backup power*
 - LL + Uninterruptible Power Supply (UPS): 13%
 - *UPS for short-term PQ protection*
 - *~3% are equipped with PQ module with PQ ≥ 3*

NAS Projects $\geq 500\text{kW}$ Through March 2002

No.	Customers	Site	Market	NAS kW/kWh	Application	Start of Operation
2	TEPCO	Kawasaki SS	EPC	500/4000	LL	Jun-95
10	TEPCO	Tsunashima	EPC	6000/48000	LL	Mar-97
(2000kW relocated to Project 19)						
14	NGK	Head Office	Comml	500/4000	LL	Jun-98
18	TEPCO	Ohito SS	EPC	6000/48000	LL	Mar/Oct 99
(1000kW relocated to Projects 58 and 62, 4000kW to Project 86)						
19	Toko Electric	Saitama	EPC	2000/16000	LL	Jun-99
22	Chubu EPC	Odaka SS	EPC	1000/8000	LL	Mar-00
28	TEPCO	Tsunashima SS	EPC	2000/14400	LL	Nov-00
(2000kW relocated to Project 86)						
33	TEPCO	Shinagawa SS	EPC	2000/14400	LL	Mar-01
(2000kW relocated to Project 86)						
46	TEPCO	Asahi Brewery	Indl	1000/7200	LL+EPS	Oct-01
47	TEPCO	Takaoka	Indl	600/3600	LL	Oct-01
49	City of Tokyo	Kasai Water No.1	WTP	1200/7200	LL+EPS	Dec-01
		Kasai Water No.2	WTP	1200/7200	LL+EPS	Aug-03
		Kasai Water No.3*	WTP	480/2880	LL	Jan-04
(*480kW relocation from Hachijo Island)						
51	TEPCO	Fuji/Zerox	Indl	1200/7200	LL	Mar-02
52	TEPCO	Takaoka	Indl	800/5760	LL	Mar-02
55	TEPCO	Pacifico	Special*	2000/14400	UPS	Mar-02
(*2002 World Soccer Cup. Subsequently relocated to Project 78)						

Demo Project	Comm'l Project
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NAS Projects \geq 500kW (June 2002 thru March 2004)

No.	Customers	Site	Market	NAS kW/kWh	Application	Start of Operation
56	TEPCO	Chichibu SS	EPC	1000/7200	LL	Jun-02
57	TEPCO	Fujitsu	Indl	3000/7200	LL+UPS(PQ=3)	Jun-02
58	TEPCO	Super Market	Comml	1000/8000	LL	Aug-02
59	AEP	Office Building	Comml	500/720	LL+UPS(PQ=5)	Sep-02
60	TEPCO	Honda/Tochigi	Indl	1800/10800	LL	Dec-02
62	TEPCO	Super Market	Comml	1200/8000	LL	Feb-03
64	City of Tokyo	Shinmachi	Comml	500/2160	LL+UPS	Mar-03
67	TEPCO	Tokyo Dome	Comml	1000/7200	LL+EPS	Apr-03
68	TEPCO	Mitsui Norin	Comml	1500/3600	LL+UPS(PQ=3)	May-03
69	TEPCO	Pharmacy Plant	Indl	600/1800	LL+UPS	May-03
70	NGK	Komaki	Indl	600/3600	LL+UPS	May-03
71	TEPCO	University	Comml	1200/8000	LL+EPS	Jul-03
72	TEPCO	Hospital	Comml	600/2000	LL+UPS	Jul-03
73	TEPCO	Super Market	Comml	900/6000	LL	Aug-03
74	TEPCO	Department Store	Comml	1200/8000	LL	Aug-03
76	TEPCO	Chemical Plant	Indl	2400/16000	LL+EPS	Sep-03
77	TEPCO	Government Office	Comml	1200/8000	LL+EPS	Dec-03
78	TEPCO	Video Manufacturer	Indl	2400/16000	LL+EPS	Feb-04
79	TEPCO	Matuso SS	EPC	2000/14400	LL	Feb-04
89	TEPCO	Perfume Factory	Indl	1200/8000	LL+EPS	Mar-04
84	City of Saga	City Hall	Comml	600/3600	LL+EPS	Mar-04
85	Kyushu	Boat Racing	Comml	2400/14400	LL+EPS	Mar-04
86	Yamagata Pref.	Murayama Sewage	WTP	600/3600	LL	Mar-04
81	TEPCO	Kamiyama SS	EPC	2000/14400	LL	Mar-04
82	City of Fukuoka	Subway Office No.1&2	Comml	1200/7200	LL	Mar-04

Demo Project	Comm'l Project
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NAS Projects \geq 500kW (April to December 2004)

No.	Customers	Site	Market	NAS kW/kWh	Application	Start of Operation
86	TEPCO	Morigasaki PFI	WTP	9600/64000	LL	Apr-04
95	City of Fukuoka	Subway Office No.3	Comml	2400/14400	LL+EPS	Apr-04
90	TEPCO	Super Market	Comml	1200/8000	LL	Jun-04
91	TEPCO	Camera Mfr.	Indl	1800/12000	LL+EPS	Jun-04
92	TEPCO	Nippon Tobacco	Indl	4800/28800	LL	Jun-04
93	TEPCO	Hitachi Automotive	Indl	9600/64000	LL	Jul-04
94	TAIYO Pharmacy	Takayama	Comml	1200/8000	LL+EPS	Jul-04
96	TEPCO	Hospital	Comml	600/4000	LL+EPS	Aug-04
97	TEPCO	Department Store	Comml	2400/16000	LL	Aug-04
98	TEPCO	Milk Distribution	Indl	1200/8000	LL	Aug-04
99	TEPCO	Super Market	Comml	1200/8000	LL+EPS	Sep-04
100	TEPCO	University	Indl	2400/16000	LL	Oct-04
101	TEPCO	Aircraft Mfr.	Indl	4800/32000	LL	Oct-04
103	TEPCO	Nonferrous Metal Mfr.	Indl	2400/16000	LL+EPS	Nov-04
104	TEPCO	Nonferrous Metal Mfr.	Indl	3600/24000	LL	Nov-04
102	TEPCO	Government Office	Comml	2400/14400	LL+EPS	Dec-04
105	TEPCO	Camera Mfr.	Indl	1200/8000	LL+EPS	Dec-04
106	Yamagata Pref.	Pkitama Water Treatment	WTP	600/3600	LL+EPS	Dec-04
107	World Exposition	Nagoya	Indl	600/4000	LL+EPS	Dec-04
108	TEPCO	University	Indl	1200/8000	LL	Dec-04

NAS Battery Attributes

- **Commercial reality in Japan – ready for global market**
- **No barriers to high volume, low cost production – abundant materials, ceramics mfg and automated production verified**
- **Superior energy density – small footprint**
- **Superior pulse power capability – seconds to 10s of minutes**
- **Easily sited outdoors and indoors; no emissions, noise or vibrations; relocatable if mission changes**
- **15 year life and high cycle life: 2500 cycles for 100% DOD, 4500 for ~90% DOD, 6500 for ~65% DOD, etc**
- **High DC efficiency, insensitive to ambient temperature, no self discharge, no memory effect**
- **Prompt response – full power charge to discharge in 1 msec**
- **Remote operation and minimal planned maintenance, i.e., periodic inspection – no pumps, valves, heat xchgrs, etc**
- **Safety and high reliability confirmed via extensive testing and demonstrations**

NAS Value Components Within Target Markets

- **High value NAS projects for market entry adapt combinations of the following applications**
 - **Peak Shaving or Load Leveling, e.g., 3 to 10 hours daily of shifting off-peak energy to offset peak energy demands**
 - **Power Quality support, e.g., seconds to minutes for voltage sag and outage mitigation, plus bridge to generation**
 - **Standby Power, e.g. hours for backup power – prompt to delayed**
 - **“Prompt” spinning reserve, e.g., 15 minutes for grid frequency support and contingency optimization,**
 - **Ancillary Services, e.g., regulation control – up and down, conventional spinning reserves, black start, reactive power support**
 - **Renewables Optimization, e.g. seconds to minutes for stabilization of wind fluctuations; hours for curtailment or spillage mitigation, or forecasting hedge to minimize imbalance payments, or bulk time-shift of generation**
 - **Improved utility asset utilization and reliability via distributed and relocatable energy storage that avoids or defers system upgrades to serve peak and/or premium load requirements**

Examples for High Value Combined Applications

Distribution Utility (DU)

- Load Leveling: 6 MW, 38 MWh Weekday Load Shifting
 - Distribution System Upgrade Deferral/Avoidance
 - Reduced T Demand and Energy Charges(**)
- Plus 5 MW, 5 MWh for Voltage Sag and Outage Protection
 - Premium PQ Customer Service
- Plus 5 MW, 1.25 MWh for as Available Regulation Control (**)
 - Added Revenue per Market Rates

Energy Services Based Utility or Provider

- 3 MW, 30 seconds for Voltage Sag and Outage Protection
 - Premium PQ Customer Service
- Plus 1 MW, 7 MWh for Daily Peak Shaving
 - Reduced Energy and T & D Demand Costs for Customer
 - As Available from DU, Demand Response/Reduction Payments

Transmission and Generation Based Utility or Wind Generator

- Prompt Spinning Reserve: 20 MW, 7.5 MWh for Bridge to Generation
 - Avoided Alternative Solution, including Load Interruption(**)
- Plus 10 MW, 35 MWh for Daily Shift of Off-Peak Load to Peak Source
 - Higher Value for Firm, Peak Generation
 - Stabilize Wind Fluctuations – Reduce Regulation Impact Cost
- Plus 10 MW, 2.5 MWh for as Available Regulation Control
 - Revenue per Market Rates

(**) : Value accrual uncertainties