

Doosan Heavy Industries & Construction Co.,Ltd.

NUCLEAR BUSINESS



Building your tomorrow today



GLOBAL LEADER IN POWER & WATER

Nuclear power plants are the only viable large-scale alternative to the fossil fuels power plant. They generate clean electricity that do not contribute to global warming. People's attitudes toward nuclear power have been changing, and Doosan is ready to supply some of the world's safest and most trustworthy nuclear power plants.



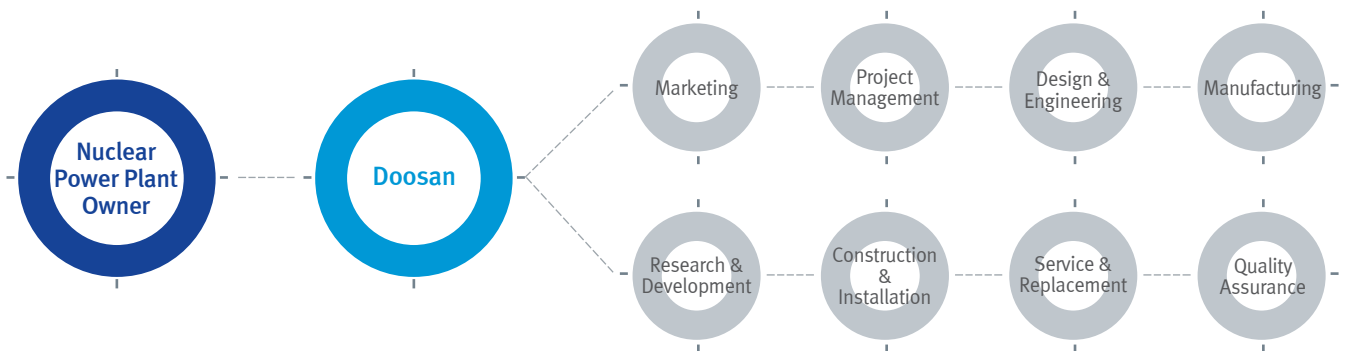
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INTRODUCTION

In proportion to the rapid development of Korea's economy, the demand for electricity has been increased just as quickly. As a leading supplier of Korean nuclear equipment, it has been Doosan's responsibility to meet this demand.





Doosan entered the business of nuclear power generation starting with the construction of its Changwon plant in 1976 and supplied power plant system to Hanbit nuclear power plant units 1 and 2 until 1986. The period between the two events is known as the 'Technology Implementation Stage' for the company. It was during this time when the company first introduced and implemented the new technology for building nuclear power generation systems and laid the foundation for building such systems by setting up a quality assurance system for nuclear power generation.

Doosan was able to accumulate experience through technology transfer and by carrying out projects after being selected as the main contractor for supplying nuclear steam supply systems for Hanbit units 3 & 4 in 1987. By that time, Doosan already had enough production facilities to develop the main systems. This brought about a significant advancement in the design and production of materials and systems. In addition, by carrying out the Hanul units 3 & 4 project, Doosan was in the stage of technological advancement for its nuclear power business. Doosan began to independently design Hanul units 3 & 4 based on the experience it gained by carrying out the Hanbit units 3 & 4 project and sent its engineers overseas to receive training in the area of production where it lacked the technology as part enhance its capabilities in nuclear power technology.

After its successful completion of Hanul units 3 & 4, Doosan realized its dream of having the technology to design and manufacture main nuclear power systems. Along with this, Doosan also signed a steam generator supply contract for China's Qinshan units 1 & 2 (phase III) in 1997. The company was eventually recognized by the global market for its technological prowess by exporting main nuclear power systems to China and then to the US. This marked the beginning of Doosan's technological independence. After that, the company proceeded to also develop the RCP and MMIS technology while carrying out Korea's Nu-tech 2012 project.

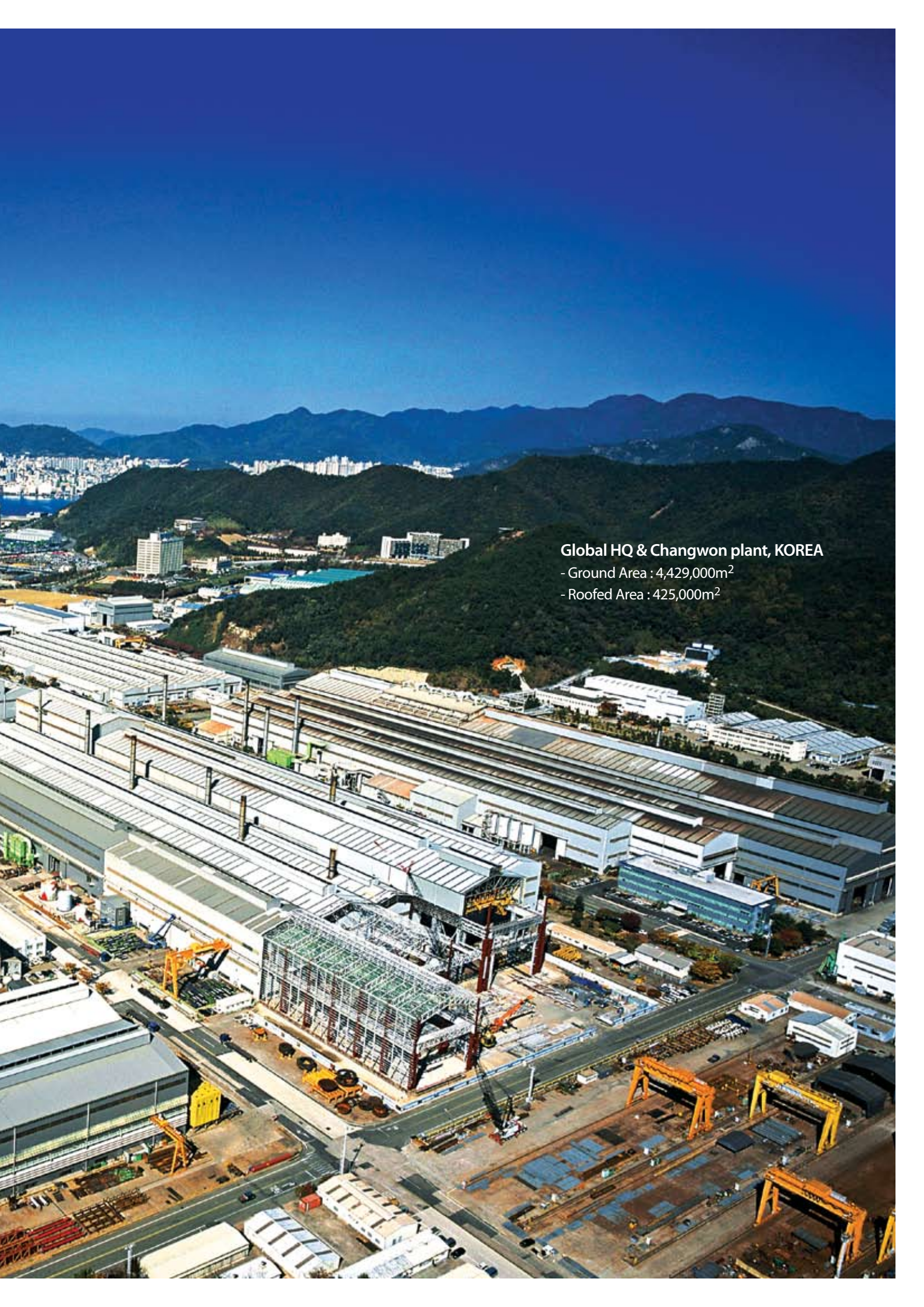
Doosan, as a member of the 'Korea Team' that will export the APR1400 while also continuing to build more power plants in Korea, Doosan will also play a key role in exporting Korean advanced nuclear power system (APR1400) to Middle East and Asia. Furthermore, most countries wishing to import nuclear power systems believe local contents will serve as their KSF (Key Success Factor) for building more nuclear power plants. Doosan will help these countries develop their own technology, and Doosan will have a higher chance of becoming an industry leader in nuclear power production.

Doosan Heavy Industries & Construction Co.,Ltd.

INTEGRATED MANUFACTURING COMPLEX : Changwon Plant

At Doosan, we've consistently brought excellence in engineering, procurement, manufacturing, construction, and service to clients around the world since 1962, We've helped utilities build over 680 thermal, combined-cycle, and nuclear power units representing almost 200GW of installed capacity to date in over 30 countries. And along the way, our technical innovations and commitment to total client satisfaction have made us a global leader in power and water.





Global HQ & Changwon plant, KOREA

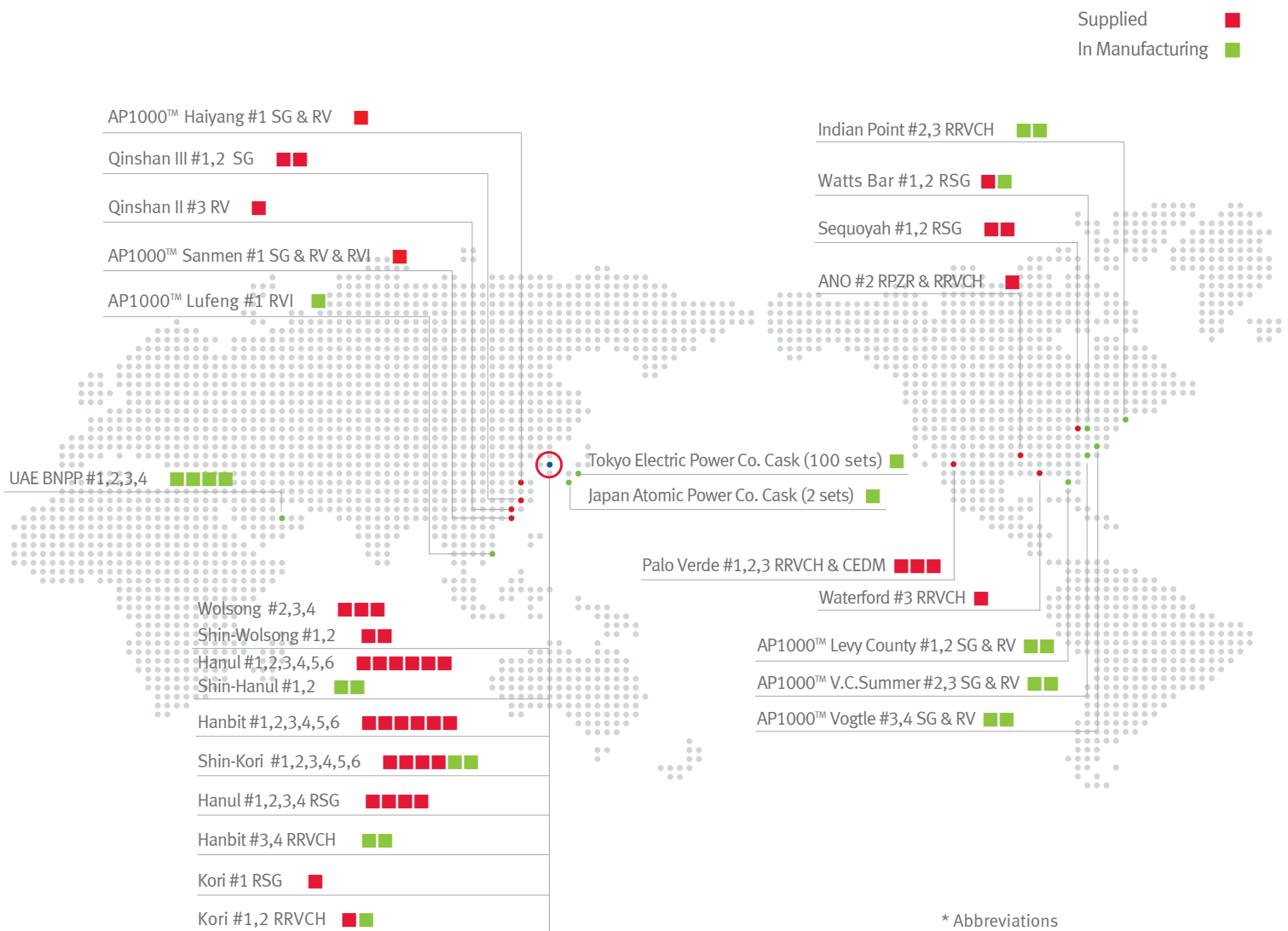
- Ground Area : 4,429,000m²

- Roofed Area : 425,000m²

EXPERIENCES

Doosan is Korea's only company that specializes in NSSS (Nuclear Steam Supply System) for nuclear power plants and possesses the highest level of technology. With its NSSS production lines and management systems for design, material, manufacturing, construction, testing, services, maintenance and repair, Doosan is strengthening its position as a leading provider of NPPs in both domestic and overseas markets. Since Hanbit units 1&2, Doosan has so far supplied equipments to total of 21 domestic nuclear power plants.

Worldwide Experiences



* Abbreviations
 - RV : Reactor Vessel
 - RVI : Reactor Vessel Internals
 - SG : Steam Generator
 - RRVCH : Replacement Reactor Vessel Closure Head
 - RSG : Replacement Steam Generator

▣ Domestic Experiences



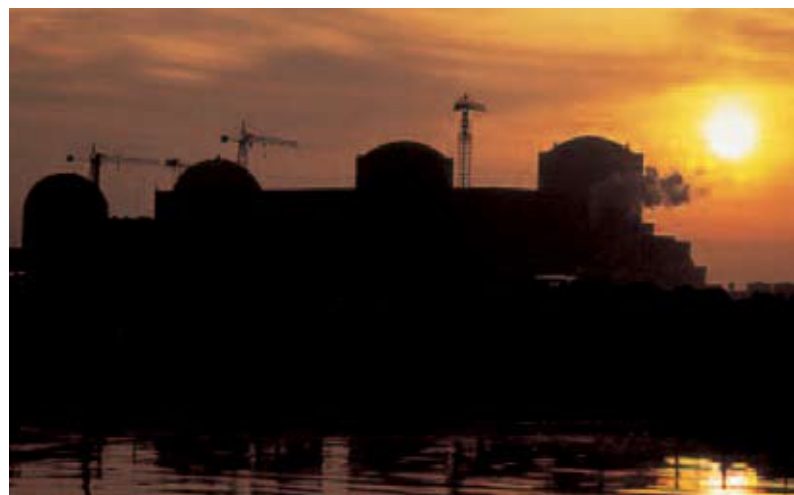
Hanbit Nuclear Power Plants (HBN #1,2,3,4,5,6)



Hanul Nuclear Power Plants (HUN #1,2,3,4,5,6)
Shin-Hanul Nuclear Power Plants (SHN #1,2)



Wolsong Nuclear Power Plants (WSN #2,3,4)
Shin-Wolsong Nuclear Power Plants (SWN #1,2)

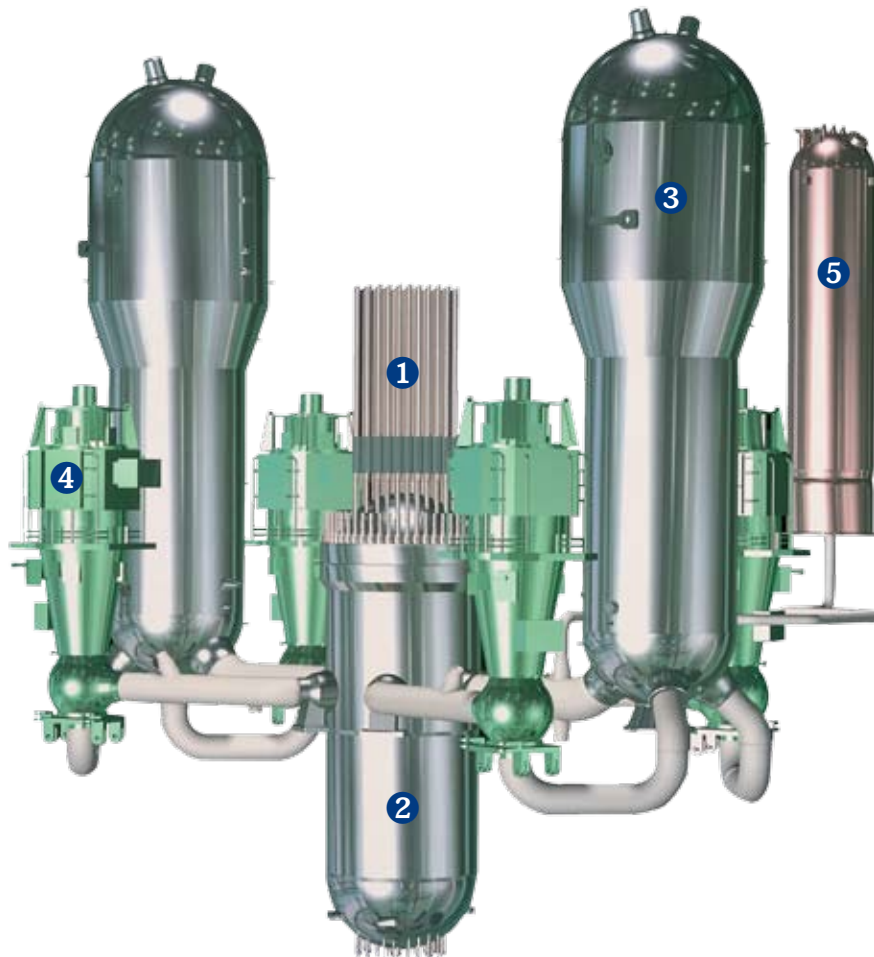


Shin-Kori Nuclear Power Plants (SKN #1,2,3,4,5,6)

FEATURES OF APR1400

REACTOR COOLANT SYSTEM

The Reactor Coolant System (RCS) is designed to remove heat from the reactor core. RCS of APR1400 consists of one reactor vessel, two Steam Generators, four Reactor Coolant Pumps and one Pressurizer connected to a hot leg. These major components are designed to have a lifetime of 60 years and the seismic design basis of 0.3g SSE is applied to strengthen the resistance to earthquake.



Design Characteristics

Parameters	Design Value
Hot leg diameter (in)	42
Cold leg diameter (in)	30
Operating pressure (psia)	2,250
Reactor inlet temperature (°F)	555
Reactor outlet temperature (°F)	615
Design Pressure (psia)	2,500
Design temperature (°F)	650
Hydrostatic test pressure (psia)	3,125
Total reactor coolant volume (ft ³)	16,020
Total RCS minimum design flow (gal/min)	446,300

- ① Control Element Drive Mechanism
- ② Reactor Vessel
- ③ Steam Generator
- ④ Reactor Coolant Pump
- ⑤ Pressurizer

MANUFACTURING CAPABILITY

As the main contractor for Korea's NSSS (Nuclear Steam Supply System), Doosan maintains the highest level of technology meeting all international standards for manufacturing and quality. Doosan has established its position as a leading supplier of nuclear power components for the international markets and is applying its know-how and experience in a "one-stop" service to cover NSSS production lines of design, raw material, manufacturing, testing, construction and services.

▣ Made in Doosan - From Forging Material to Services



1 Forging



2 Manufacturing



3 Assembly



4 Testing



5 Shipping

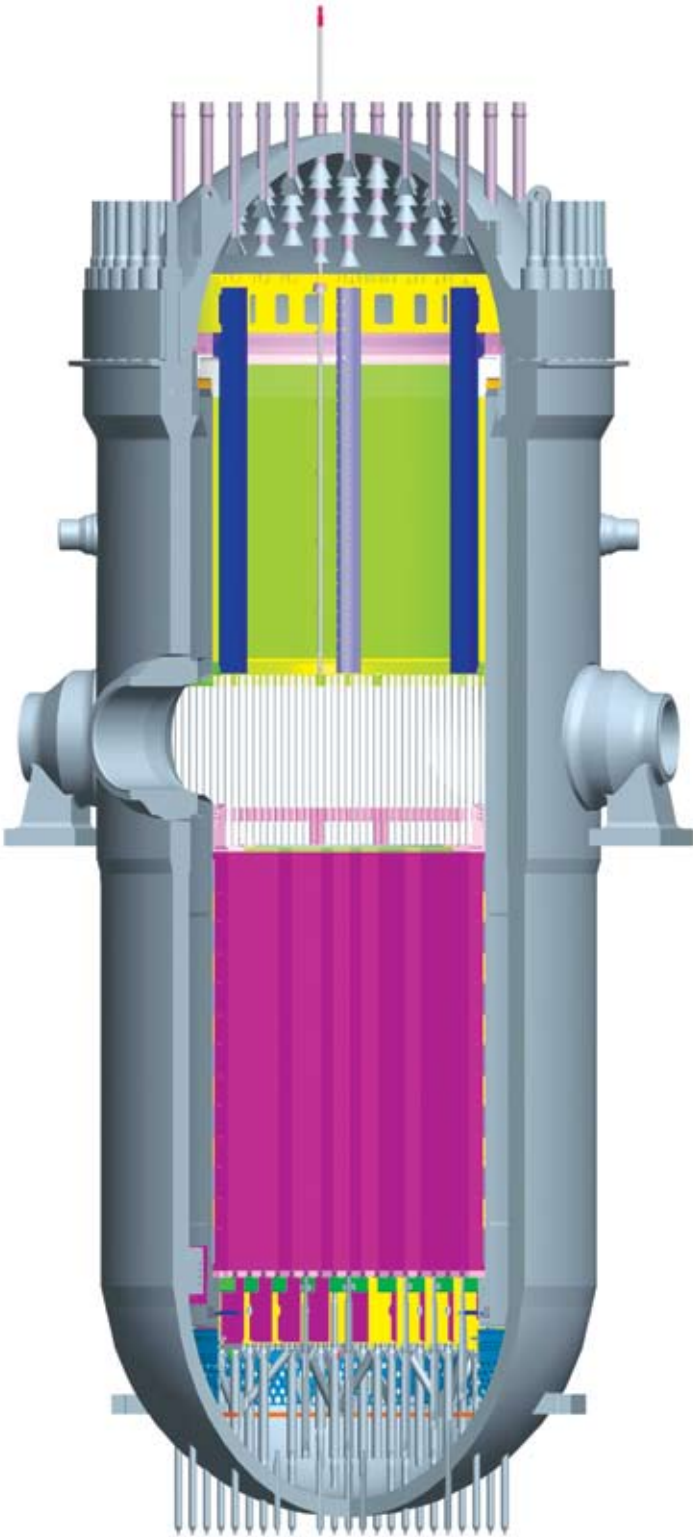


6 Installation

FEATURES OF APR1400

REACTOR VESSEL

The Reactor Vessel designed to withstand high pressure and temperature contains nuclear internals and fuel. The Closure Head is removable to reload the fuel, while the Reactor Vessel is fabricated from ring-forged shells. To enhance safety, APR1400 adopts 4 Direct Vessel Injection Nozzles, which inject the coolant water of Safety Injection Tank into the core directly.



Design Characteristics

Parameters	Design Value
Design pressure (psia)	2,500
Design temperature (°F)	650
Inside diameter at shell (in)	182-1/4
Overall height of vessel and enclosure head (ft-in)	48 7-7/8
Minimum cladding thickness (in)	1/8



Forged Shell Manufacturing

The major part of Reactor Vessel is fabricated from forged material. These ring-forged shells eliminate the need for longitudinal seam welds thereby reducing production and inspection time. Materials of the Reactor Vessel are carefully selected to withstand high pressure, temperature, and radiation.

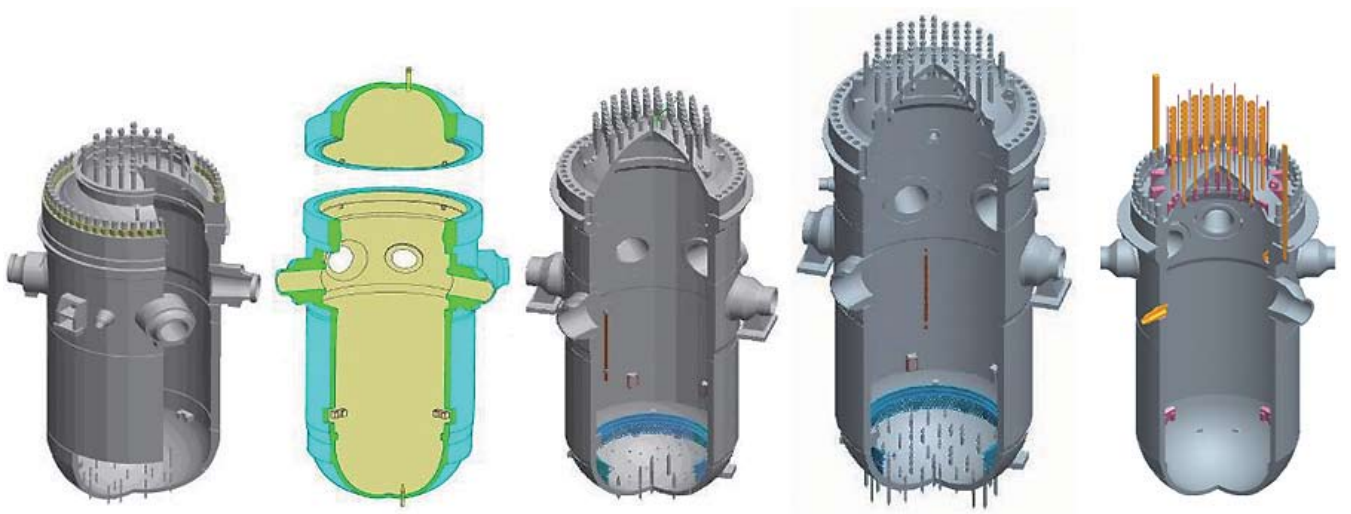
Shell & Nozzle, Bottom Head Welding

The Reactor Vessel is composed of shells, nozzles and domes. The shells are first welded together. Then holes are machined to the shell for the assembly of nozzles. Finally, the shell and bottom head dome are welded to form the complete assembly.

Closure Head Assembly

The Reactor Vessel can sustain pressure by tensioning of studs at closure head. At the Closure Head, 108 nozzles are installed for the connection with Control Element Drive Mechanisms. The Closure Head Assembly and the Vessel are sealed by 54 Studs and 2 O-Rings. The Pad & Lug welded over the Closure Head surface are installed for supporting the Integrated Head Assembly.

▣ Various types supplied by Doosan



650 MWe
(Qinshan/China)

950 MWe
(Hanul #1,2/Korea)

1,000 MWe
(OPR1000/Korea)

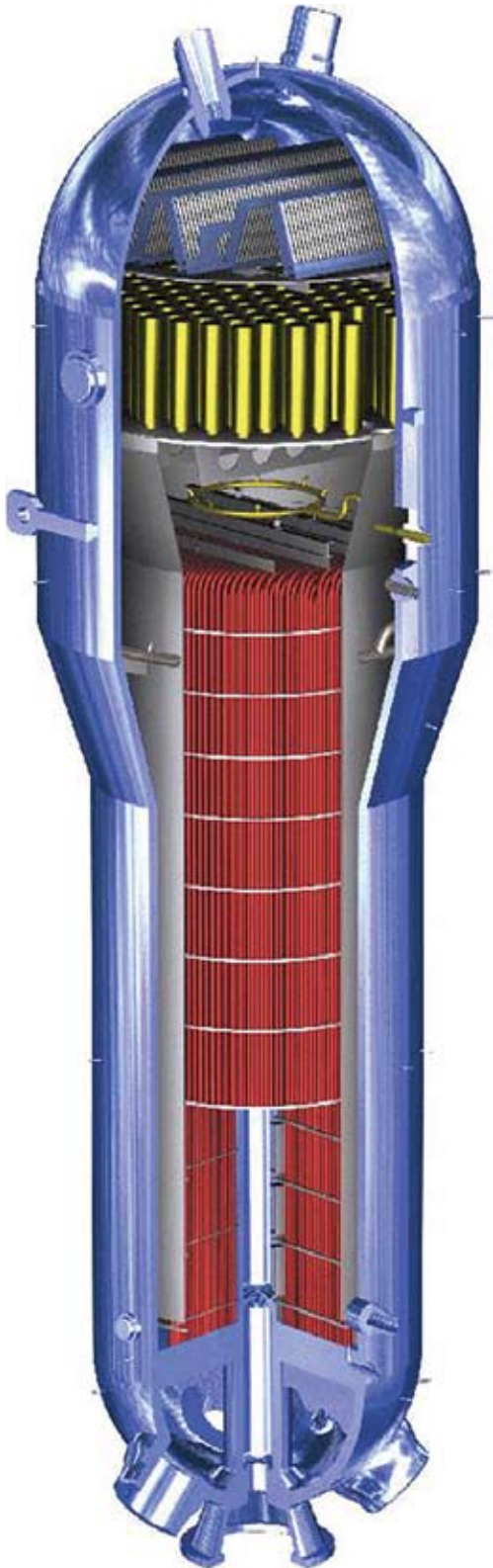
1,400 MWe
(APR1400/Korea, UAE)

1,000 MWe
(AP1000™/China, USA)

FEATURES OF APR1400

STEAM GENERATOR

The Steam Generator is a type of heat exchanger which provides steam to drive the turbine generator. While heat is exchanged from the Primary Coolant Loop to the Secondary Coolant Loop within the Steam Generator, the coolant within each loop is isolated from the other.



Design Characteristics

Parameters	Design Value
Number of SGs	2
Number of tube per SG	13,102
Tube material	Alloy 690
Heat transfer area (ft ²)	163.67
Tube side operating pressure (psia)	2,250
Shell side maximum operating pressure (psia)	1,100
Steam pressure at full power (psia)	1,000
Steam temperature at full power (°F)	545
Steam flow per SG at full power (lb/hr)	8.975 x 10 ⁶
Maximum moisture at outlet at full power (w/o)	0.25



Material

The Steam Generator is fabricated from ring forged shells and from close die forged heads. These forgings eliminate the need for longitudinal welds thereby reducing production and inspection time. Materials of Steam Generator are carefully selected to withstand high pressure, temperature and radiation.

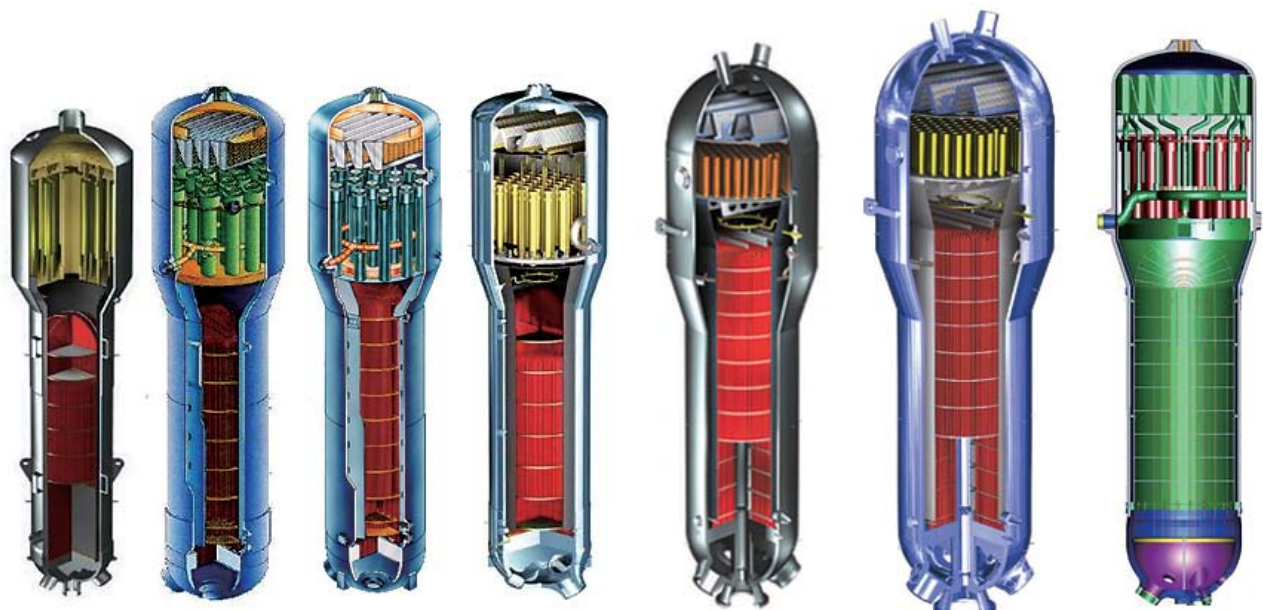
Tube Sheet Drilling

The tubesheet has drilled holes for Installation of U-bend tube using 3-spindle deep hole drilling machine.

Tube Installation

The U-bend tubes are installed, then carefully expanded the diameter of tube sheets. The expansion process shall be carefully controlled so as to produce as low as residual stress in the tubes as is reasonably achievable.

▣ Various types supplied by Doosan



700 MWe
(CANDU
/China)

587 MWe
(Kori #1
RSG/Korea)

950 MWe
(Hanul #1,2
RSG/Korea)

1,174 MWe
(Sequoyah #1,2
RSG/USA)

1,000 MWe
(OPR1000
/Korea)

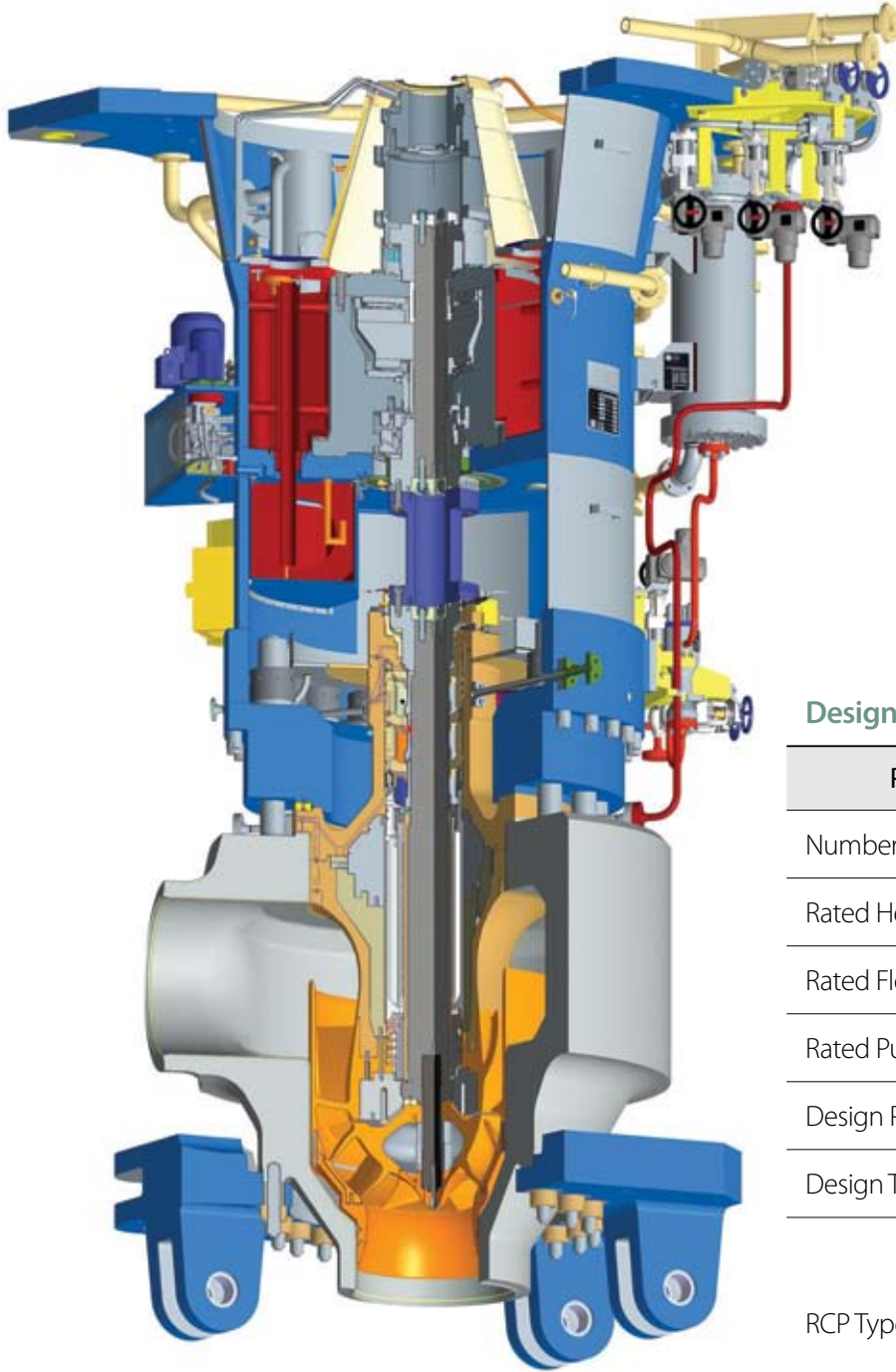
1,400 MWe
(APR1400
/Korea, UAE)

1,000 MWe
(AP1000™
/China, USA)

FEATURES OF APR1400

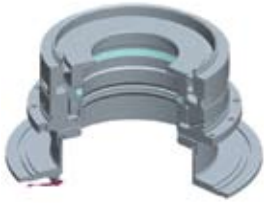
REACTOR COOLANT PUMP

The Reactor Coolant Pump (RCP) is single stage centrifugal pump with cantilevered impeller and vertical shaft with hydrodynamic mechanical seals. The RCP located in Reactor Coolant System circulates reactor coolant from two Steam Generators to the Reactor Vessel and back to the Steam Generators.



Design Characteristics

Parameters	Design Value
Number of RCP	4
Rated Head (ft)	375
Rated Flow (gpm)	121,600
Rated Pump Speed (rpm)	1,190
Design Pressure (psia)	2,500
Design Temperature (°F)	650
RCP Type	Vertical Single-Stage Centrifugal Volute Pump Bottom Suction & Horizontal Discharge
Brake Horse Power (HP)	13,900



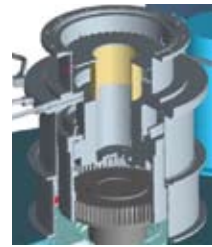
3 Oil Feed Device

- Oil Feed Device is designed to boost circulation of oil in axial & radial bearing by its own blade in the upper bearing housing
- High torque is transferred via special toothed naves and a coupling sleeve.



2 Thrust & Radial Oil Bearing

- Axial bearing is a tilting pad bearing, both main and reverse thrust Jacking oil feed in the main thrust pads.



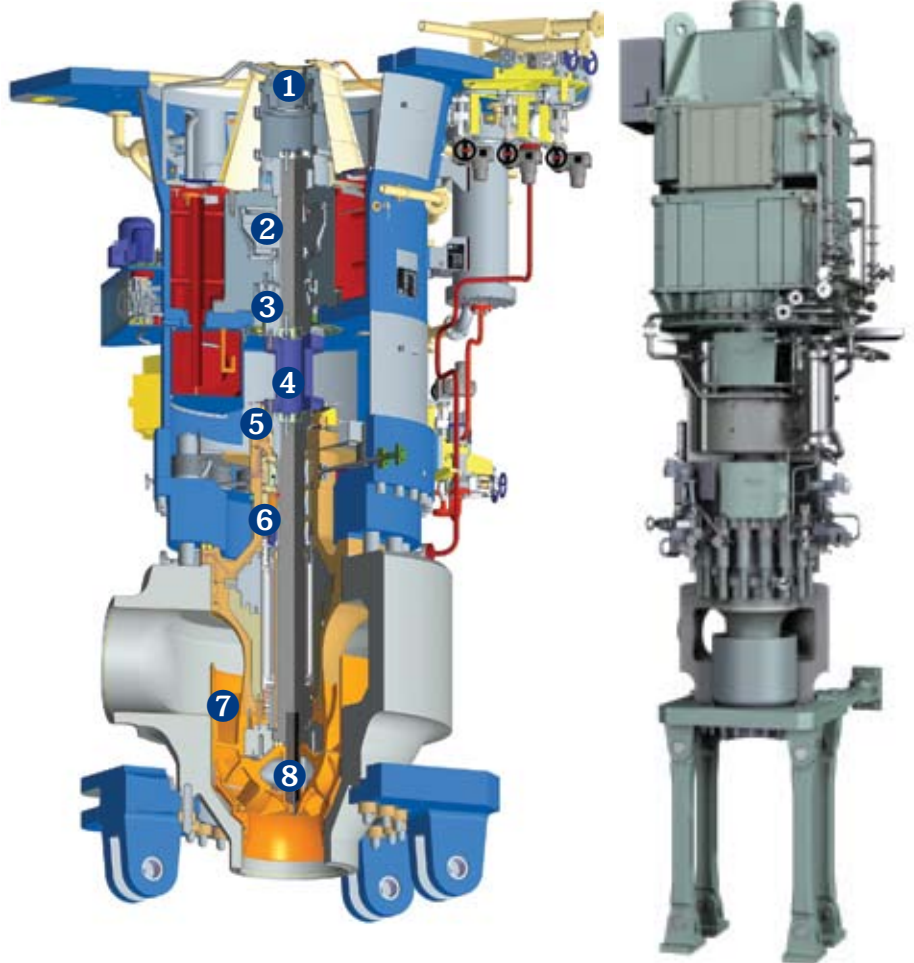
1 Curved Teeth Coupling

- Designed as flexible coupling, torque is transferred via special toothed naves and a coupling sleeve.



4 Removable Shaft Section

- Removable shaft section is designed to be possible to change upper and lower seals without removing other parts.



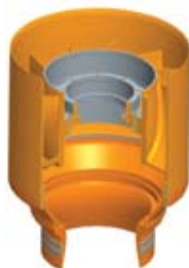
5 Stand Still Seal

- In case of seal failure pressure boundary can be closed by stand still sea.



6 3rd Stage Hydrodynamic Seal

- Hydrodynamic effect even at low speed
- No mixed friction at low thermal load
- No thermal deformations due to friction
- Sufficient circulation and cooling.



7 Diffusor

- 11-vane diffusor, other surfaces like water passages between diffusor blades are finished by shot peening.



8 Impeller

- Closed semi-axial impeller, 6-blade
- Back blades are assisting pressure difference for emergency injection water supply.

FEATURES OF APR1400

MAN MACHINE INTERFACE SYSTEM

Man Machine Interface System (MMIS) is equivalent to the brain and nerve system of a nuclear power plant. It monitors and controls the operating conditions to prevent accidents proactively.

Doosan achieved a complete development of MMIS which is core part of nuclear technology that was relied on overseas companies in the past by an accomplishment of R&D in cooperation with domestic utility, KHNP and research institutions. Doosan will make the highest quality of service for the clients as total provider of the world nuclear power plant equipment who produces safe and reliable nuclear I&C system based on global-top technology.



Features



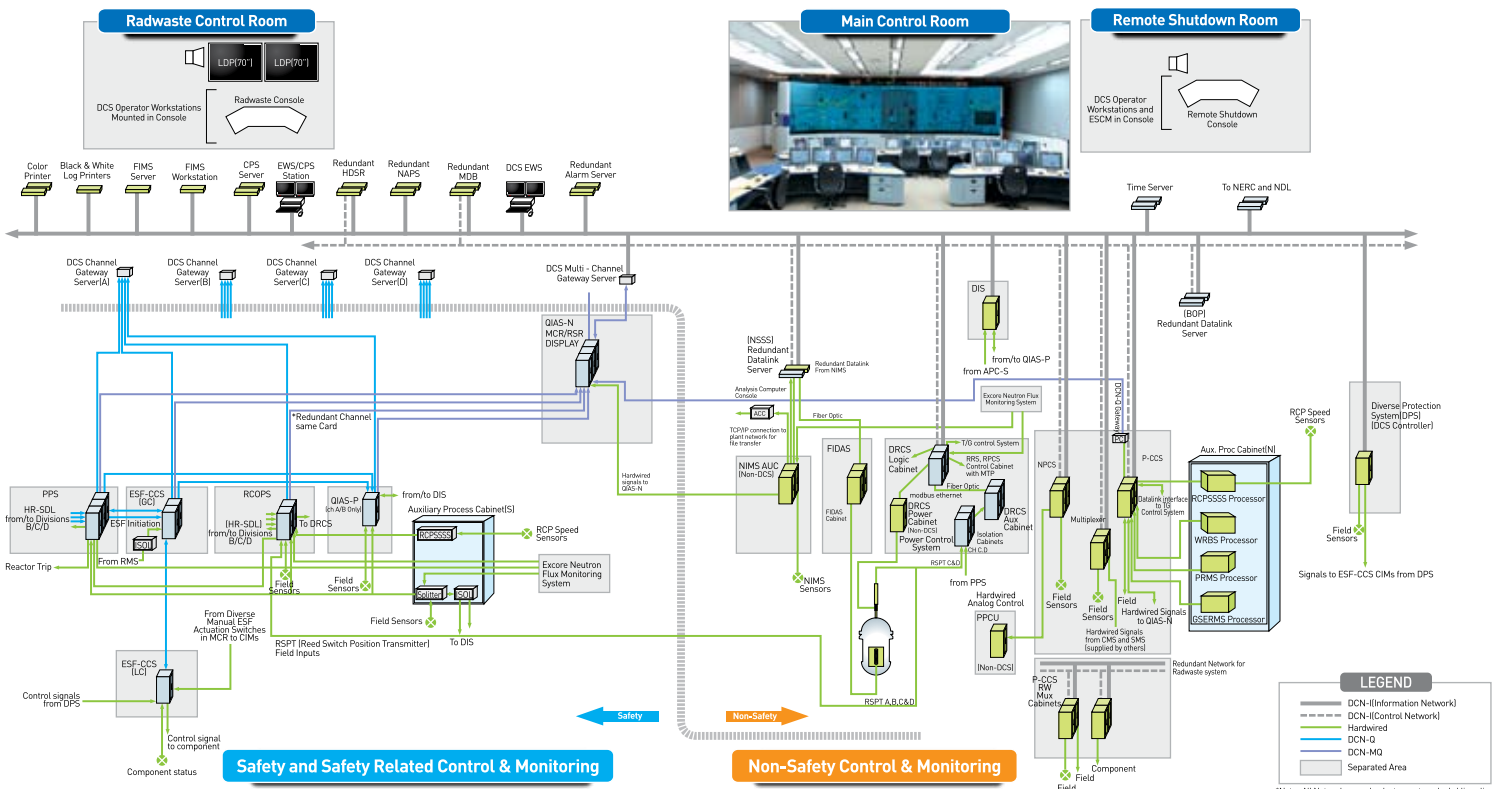
ESF-CCS



P-CCS

System	Technical Features
PPS	Coincidence processor structure (3 Rack with 3 Processor Module)
RCOPS	Improvement of CEA signal checking algorithm to avoid CEA position latching problem
ESF-CCS	Maintenance Feature : MTP/ITP in each safety system
QIAS-P	Application of redundant communication module and path
QIAS-N	Application of separated network with IPS
IPS/CPS	IPS Server and Network configuration based on DCS
PCS NPCS/DPS	Redundant power controller DC Hold Power automatic commitment
NIMS	High performance industrial computer included PCI type data acquisition device
MCR/LDP	Nuclear Steam Supply System & Balance of Plant integrated Control Design

Architecture of DOOSAN MMIS for APR1400



CPS : Computerized Procedure System	ESF-CCS : Engineered Safety Features-Component Control System	HDSR : Historical Data Storage and Retrieval
DCS : Distributed Control System	EWS : Engineering Workstation	MCR : Main Control Room
DIS : Diverse Indication System	FIDAS : Fixed In-Core Detector Amplifier System	MDB : Main Data Base
DRCS : Digital Rod Control System	FIMS : Field Instrument Management System	NDL : Nuclear Data Link
NAPS : Nuclear Application Programs	PCCS : Process Component Control System	RSR : Remote Shutdown Room
NIMS : NSSS Integrity Monitoring System	PPS : Plant Protection System	RCOPS : Reactor COre Protection System
NPCS : NSSS Process Control System	QIAS-P : Qualified Indication and Alarm System - PAMI	RCPSSS : RCP Shaft Speed Sensing System
NSSS : Nuclear Steam Supply System	QIAS-N : Qualified Indication and Alarm System - Non Safety	



CRCS

Other Products

- Control Rod Control System (CRCS)
- Control Element Drive Mechanism Control System (CEDMCS)
- Main Control Room (MCR)
- Fuel Handling Equipment (FHE)
- Vital Bus Power Supply System (VBPSS)
- Motor Generator Set (MG-SET)
- Reactor Trip Switchgear System (RTSS)
- Gas Stripper & Boric Acid Concentrator Instrumentation and Control (GS- BAC I&C)



MG-SET

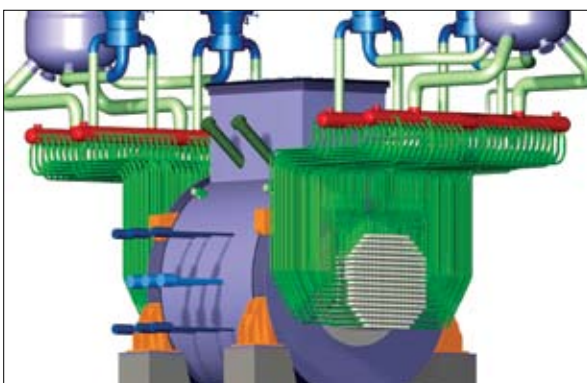
PRESSURIZED HEAVY WATER REACTOR

Doosan also supplied the major components of the PHWR (Pressurized Heavy Water Reactor) plants at Wolsong units 2,3 & 4 and Qinshan CANDU units 1 & 2 in China. PHWR uses natural uranium which is simpler to handle and easier to process into fuel assemblies than enriched uranium.



Steam Generator (PWHR)

Four Steam Generators are installed in the RCS (Reactor Coolant System) of PHWR plant.

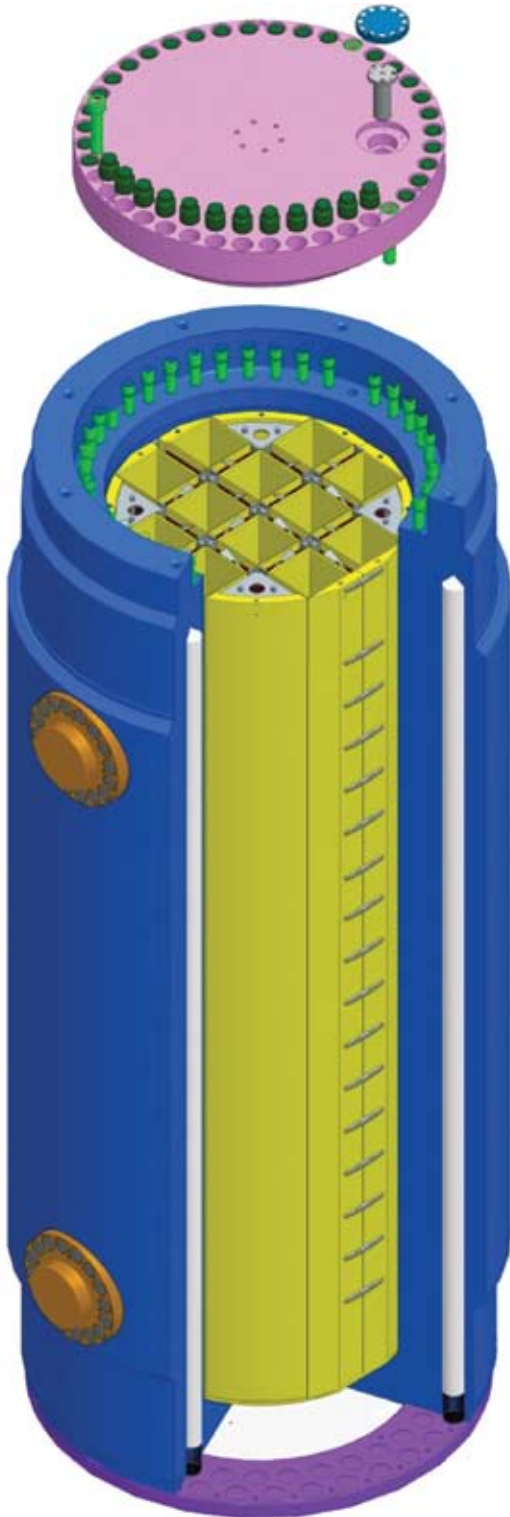


Feeder Header Assembly

The Feeder consists of several hundred pipes which transmit heated heavy water from Calandria to Steam Generator. The Header merges and distributes the coolant.

CASK

Doosan is one of the best Cask Manufacturing Companies in the world, especially. Doosan entered into Cask business in 1990 and delivered 2 sets of Cask for Kori nuclear power plant in 2002 and 1 set of Cask for Hanbit Nuclear Power Plant unit 2 and 2 sets of Cask for Hanul Nuclear Power Plant units 1 & 2 in 2007.



Experience List

Project Name	User	Delivery	Model Name	Capacity	Quantity
KSC-4	KHNP	1990.9	KSC-4	PWR Spent Fuel 4 Assembly	1 Set
Kori Cask	KHNP	2002.8	CASTOR KN-12	PWR Spent Fuel 12 Assembly	2 Set
HBN/HUN Cask	KHNP	2007.12	CASTOR KN-12	PWR Spent Fuel 12 Assembly	3 Set
TEPCO-Cask	RFS	2011~2022	NEO-Type	BWR Spent Fuel 69 Assembly	100 Set
JAPCO-Cask	RFS	2012	NEO-Type	BWR Spent Fuel 52 Assembly	1 Set



NUCLEAR SERVICES

Doosan strives to provide the best technical services and solutions to operate nuclear power plants with its engineering capabilities and manufacturing experiences.



Maintenance

Doosan retains Reactor Coolant Pump internal parts maintenance capability, including chemical decontamination. Doosan also provides inspection & maintenance services on site for refueling system.

Manufacture of Replacement equipment

Replacement equipment for all domestic and numerous overseas projects have been supplied by Doosan.

- Domestic : 12 RSGs & 4 RRVCHs
- Overseas : 12 RSGs & 7 RRVCHs

Installation of Replacement equipment

SG & RVCH Replacement for domestic nuclear power plant has been successfully performed by Doosan.

- Hanul units 3&4 SG Replacement
- Kori unit 1 RVCH Replacement

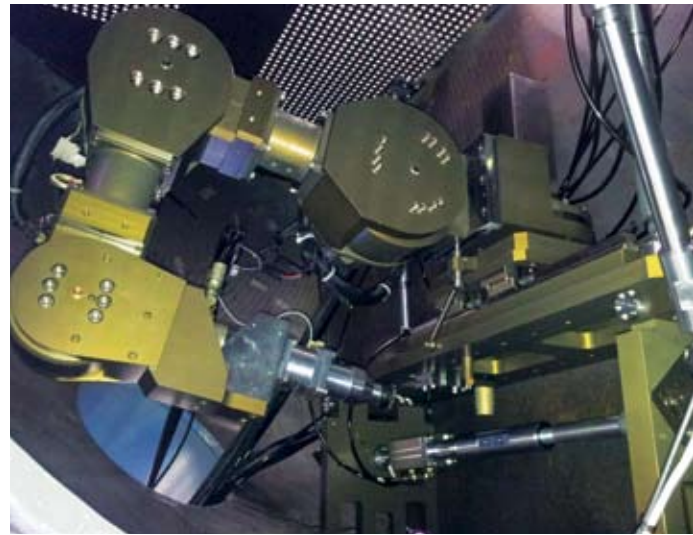
* Abbreviations

- (R)RVCH : (Replacement) Reactor Vessel Closure Head
- (R)SG : (Replacement) Steam Generator

Repair

Doosan has various facilities and extensive field experiences for Reactor Vessel (RV), Steam Generator (SG), Pressurizer (PZR) & Reactor Coolant Loop (RCL) repair.

- RV : Overlay & Seal Weld Repair of Control Element Drive Mechanism Nozzles & Vent Nozzle, In-Core Instrumentation Nozzle Repair, RV Stud Hole Inspection & Repair
- SG : Tube Plugging, Repair of Divider Plate & Nozzles, Cleaning of Tube Inside (CANDU type)
- PZR : Heater Replacement, Overlay of Dissimilar Metal Welds
- RCL : Thermal/Sleeve Removal in Safety Injection Nozzle, Repair of Resistance Temperature Detector Nozzle



Non Destructive Examination

Doosan retains 10 EPRI Performance Demonstrations and a numerous skilled staffs with NDE expert qualification and conducts Non Destructive Evaluation Inspection on operating Nuclear power plant and Pre service inspection.

- RVCH Penetration Nozzle and Vent Pipe Inspection
- ICI(BMI) Nozzle & Weld Inspection
- Reactor Coolant System Pump Shaft Inspection
- Pressure Vessel Weld Auto and Manual Ultrasonic test
- Steam Generator Tube Eddy current test



Others

Supplying Spare Parts

- Pressurizer Heater, Reactor Vessel Studs & Nuts, etc.

Upgrade and Modification

- Fuel Handling System, Integrated Head Assembly, High Density Fuel Rack, etc

Technical Advisory Service

- Installation
- Startup test

* Abbreviations

- EPRI : Electric Power Research Institute
- CANDU : Canadian Deuterium Uranium Reactor



GLOBAL NETWORK

Overseas Subsidiaries

AMERICAS

DOOSAN HEAVY INDUSTRIES AMERICA CORP.

10th Floor, Parker Plaza, 400 Kelby Street, Fort Lee, NJ 07024, USA
Tel 1-201-944-4554 31, 24
Fax 1-201-944-5022

NEWINGTON OFFICE

178 Shattuck Way, Newington, NH 03801, USA
Tel 1-603-433-5507
Fax 1-603-433-1060

PITTSBURGH OFFICE

1000 Westinghouse Drive, Building 1, 260C, Cranberry Township, PA, 16066, USA
Tel 1-412-374-6071
Fax 1-724-720-0903

DOOSAN POWER SYSTEMS ATLANTA OFFICE

1050 Crown Pointe Parkway Suite 1200, Atlanta GA 303385, USA
Tel 1-770-551-5700
Fax 1-770-551-5753

SAO PAULO OFFICE

7th Floor, Alameda Santos 787, Sao paulo, 01419-001, Brazil
Tel 55-11-2348-0100

DOOSAN ENGINEERING & SERVICES LLC

5 Paragon Drive, Montvale, NJ 07645, USA
Tel 1-201-746-8200
Fax 1-201-746-8210

DOOSAN HYDRO TECHNOLOGY, INC.

912 Chad Lane, Tampa, FL 33619, USA
Tel 1-813-805-8800
Fax 1-813-623-6092

ASIA

DOOSAN HEAVY INDUSTRIES JAPAN CORP.

2413 Mitakokusai Bldg. 1-4-28, Mita, Minato-ku Tokyo 108-0073, Japan
Tel 81-3-3452-5451~3
Fax 81-3-3452-5624

DOOSAN HEAVY INDUSTRIES VIETNAM CO., LTD. (DOOSAN VINA)

Dung Quat Economic Zone, Binh Thuan Commune Binh Son District, Quangngai Province, Vietnam
Tel 84-55-3618-900
Fax 84-55-713-008

DOOSAN HEAVY INDUSTRY & VIETNAM HAIPONG CO., LTD.

Km 92, National Highway 5, So Dau Ward, Hong Bang District, Haiphong City, Vietnam
Tel 84-31-371-2710
Fax 84-31-371-2714

DOOSAN POWER SYSTEMS INDIA PVT. LTD. NEW DELHI MAIN OFFICE

16th floor, DLF Square Building, Jacaranda Marg, Near NH-8, DLF Phase-II, Gurgaon, Haryana 122 002, India
Tel 91-124-439-8200
Fax 91-124-414-7006

NEW DELHI MARKETING OFFICE

515-5th Floor, Times Tower, M.G. Road(Opp. Central Mall), Gurgaon, Haryana 122 002, India
Tel 91-124-665-3320
Fax 91-124-665-3345

MUMBAI OFFICE

501,5th floor, CNB Square Bldg. Sangam Complex, Near Sangam Cinema, Andheri-Kurla Road, Chakala, Andheri(East), Mumbai 400 059, India
Tel 91-22-6177-0501
Fax 91-22-6177-0599

KOLKATA OFFICE

226/1 A.J.C Bose Road, 5E Trinity Building Kolkata 700 020, India
Tel 91-33-4003-3562~4
Fax 91-33-4003-3018

CHENNAI BOILER ENGINEERING OFFICE

5th Floor, Gee Gee Universal, No.2, Mc. Nichols Road, Chetpet, Chennai 600 031, India
Tel 91-44-2836-6930
Fax 91-44-2836-6936

CHENNAI BOILER MANUFACTURING

18/2A, Senneerkuppam, Bypass Road, Poonamallee, Chennai 600 056, India
Tel 91-44-6645-5555
Fax 91-44-6645-5500~1

EUROPE

DOOSAN POWER SYSTEMS LTD.

Doosan House, Crawley Business Quarter, Manor Royal, Crawley, West Sussex, RH10 9AD, UK
Tel 44-1293-61-2888
Fax 44-1293-58-4321

DOOSAN BABCOCK

Porterfield Road, Renfrew, PA4 8DJ, UK
Tel 44-141-886-4141
Fax 44-141-885-3338

DOOSAN SKODA POWER LTD.

Tylova 1/57, 301 28 Plzen, Czech
Tel 420-378-185-128
Fax 420-378-185-900

DOOSAN LENTJES GmbH

Daniel-Goldbach-Str. 19, 40880 Ratingen, Germany
Tel 49-2102-166-1111
Fax 49-2102-166-2111

DOOSAN IMGB

104 Berceni Road, Bucharest 4, Romania
Tel 40-21-301-2500
Fax 40-21-301-2701

Doosan Enpure

Doosan Enpure House Parklands Business Park Rubery Birmingham West Midlands B45 9PZ
Tel 44-0121-251-9000

Overseas Branches

AMERICAS

SANTIAGO OFFICE

Av. Nueva Tajamar 481, Torre Sur, Piso 11, Oficina 1103, Las Condes, Santiago, Chile
Tel 56-2-2657-3333
Fax 56-2-2657-3343

TAMPA OFFICE

912 Chad Lane, Tampa, FL 33619, USA
Tel 1-813-805-8800
Fax 1-813-623-6666

TAMPA WATER R&D CENTER

912 Chad Lane, Tampa, FL 33619, USA
Tel 1-813-805-8800
Fax 1-813-623-6666

ASIA

BANGKOK OFFICE

10th Floor, M-Thai Tower, All Seasons Place, 87 Wireless Road Phatumwan, Bangkok 10330, Thailand
Tel 66-2-654-0690
Fax 66-2-654-0693

BEIJING OFFICE

19th Floor, Gateway Plaza, Tower B, No. 18 Xiaguangli, North Road, East Third Ring Chaoyang District, Beijing 100027, China
Tel 86-10-8454-7122, 7136
Fax 86-10-8484-7139

HANOI OFFICE

#1101, Daeha Business Center, 360 Kim Ma, Ba Dinh District Hanoi, Vietnam
Tel 84-4-6273-0545
Fax 84-4-6273-0550

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Fax 62-21-2995-0108

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SEOUL OFFICE

465 Gangnam-daero, Seocho-Gu, Seoul
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Tel. 82-2-513-6114 Fax. 82-2-513-6200

www.doosanheavy.com

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Changwon, Gyeongnam 642-792 Korea
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