Development of Mobile Electron Accelerator for Environmental Applications

2012. 09. 25

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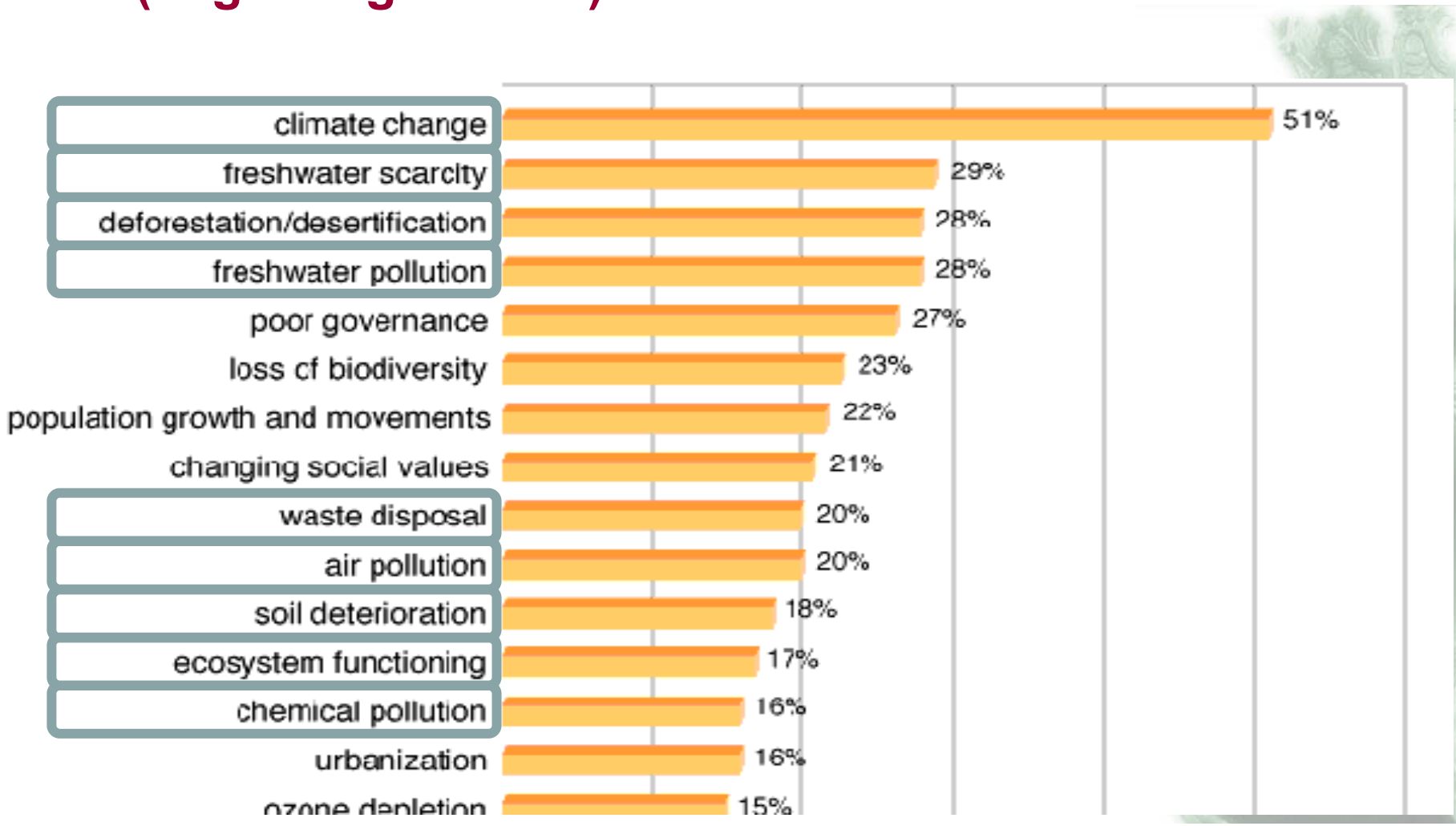
XXIII RUSSIAN PARTICLE ACCELERATORS CONFERENCE RuPAC-2012
September 24 – 28, 2012, St. Petersburg, Russia

Major emerging issues identified in the survey (beginning of 2000)



The UN Millennium Development Goals

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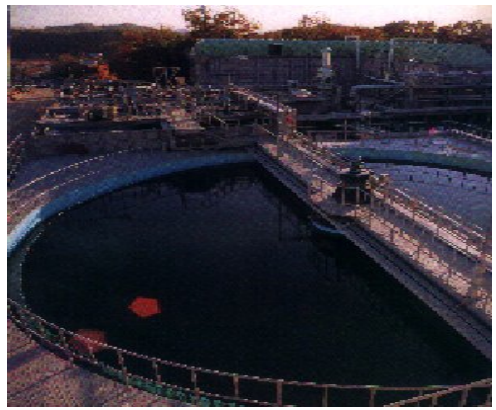
1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria, and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

Accelerator Technology for Pollution Control



Flue gas Purification

Wastewater Treatment

Sludge Hygienization

Technical Advantages of electron beam process

***. Electron Beam Technology is Eco-friendly technology**

-. No secondary waste generation

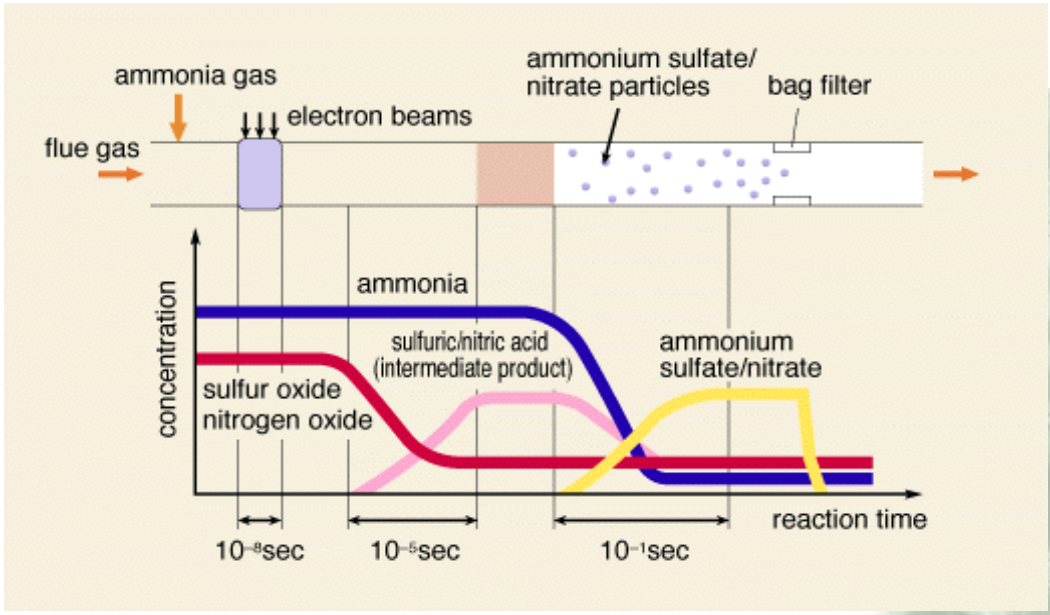
-. No catalysts, no heating and easy for automation.

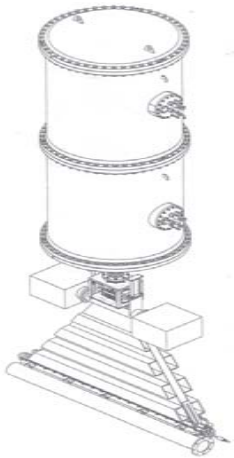
***. Experienced in pilot plant and several industrial plants**

***. Economical Advantages in capital cost and O & M cost**

***. For flue gas treatment and sludge treatment, by-products are useful for fertilizer.**

Principles of Flue Gas Purification with Electron Beam





$SO_2 \xrightarrow{} H_2SO_4 \xrightarrow{NH_3} (NH4)_2SO_4$

$NO_X \xrightarrow{} HNO_3 \xrightarrow{NH_3} NH_4NO_3$

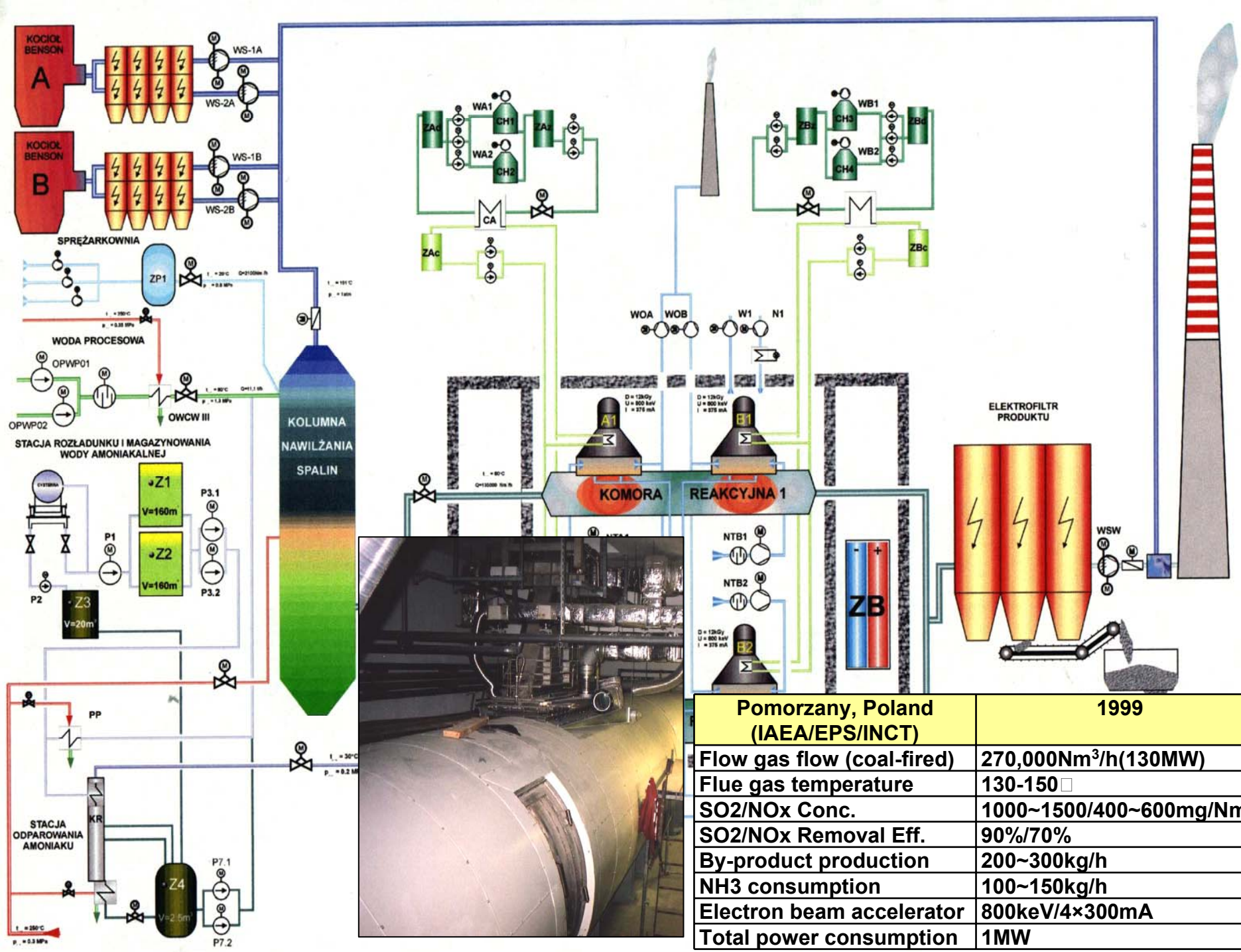
$HCl \longrightarrow NH_4Cl$

Dioxin $\longrightarrow$ Decomposed

EB Flue Gas Treatment Plant Installations in the World

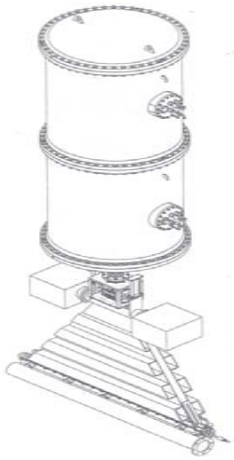
Place	Flow rate (Nm^3/hr)	Power (MW)	Accelerator	Dose (kGy)	SO_2/NOx (ppm)
Indianapolis,USA(1984)	24,000	-	800keVX2, 160kW	30	1,000/400
Badenwerk,Germany(1985)	20,000	-	300keV, 180kW	-	500/500
Kawęczyn, Poland (1992)	20,000	-	700keV, 50kW	18.8	600/250
Nagoya, Japan (1992)	12,000	-	800 keVX3, 108kW	10.5	1,000/300
Chengdu, China (1997)	300,000	90	800keVX2, 400mA 1900kW	3	1,800/400
Pomorzany, Poland (1999)	270,000	112	800keVX4, 375mA, 1200kW	10	385/340
Nisi-Nagoya,Japan(1998)	620,000	220	800 keVX6, 500mA, 2400kW	6.7	-
Hangzhou, China (2002)	305,400	-	800keVX2, 400mA 1896kW	3	1,800/400
Beijing, China (2005)	640,000	150	1000keVX2, 500mA, 1000keV/300mA, 2850kW	-	1,900/400
Svishtov, Bulgaria (2008)	600,000	120	0.9MeV/400mAx4, 1400kW	4	1680/780

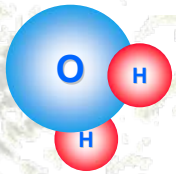
EPS Pomorzany - general view



Pomorzany, Poland (IAEA/EPS/INCT)	1999
Flow gas flow (coal-fired)	270,000Nm^3/h(130MW)
Flue gas temperature	130-150□
SO2/NOx Conc.	1000~1500/400~600mg/Nm^3
SO2/NOx Removal Eff.	90%/70%
By-product production	200~300kg/h
NH3 consumption	100~150kg/h
Electron beam accelerator	800keV/4×300mA
Total power consumption	1MW

Principles of Wastewater Treatment with E-Beam





Water Molecule

e_{aq}

OH*

H*

H_2O_2

Active Radicals

Harmful Organic in Waste-water

Complete Decomposition → H_2O, CO_2

Partial Decomposition

Suspended Solid

Monomer to Polymerization

Coagula-tion

Removal of Toxic Group

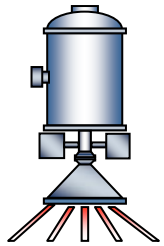
Removal of Color, Odor

Bio-Treat-ment

Types of Water/Wastewater Treatment

High contamination

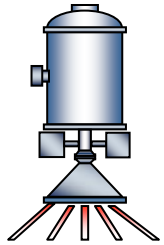
Textile dyeing wastewater
Leachate from landfill area
from petrochemical plant
from paper mills
from mines (coal, metals)
from chemical plants



→ Removal of impurities (COD, BOD, S/S etc.) → Discharge

Low or less contamination

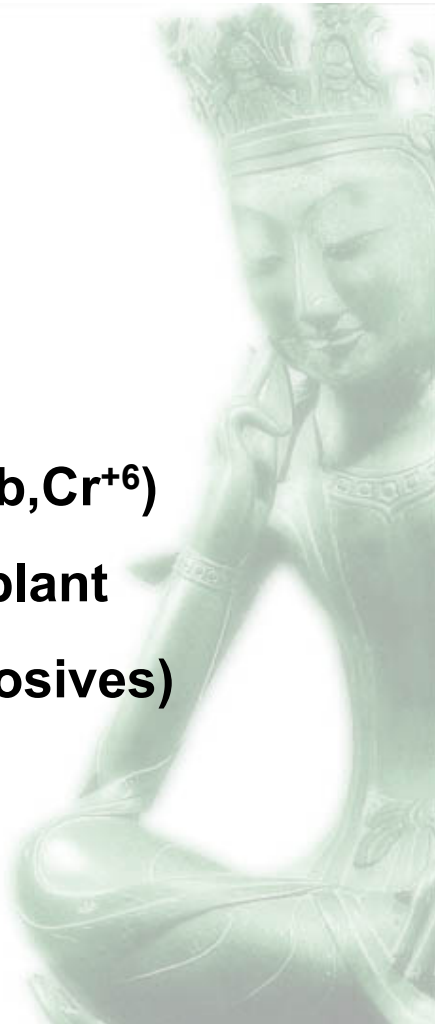
Underground water
Water from lakes or marshes
Effluent of municipal plants



→ Disinfection, Removal of Color, Odor, Residuals → Re-use

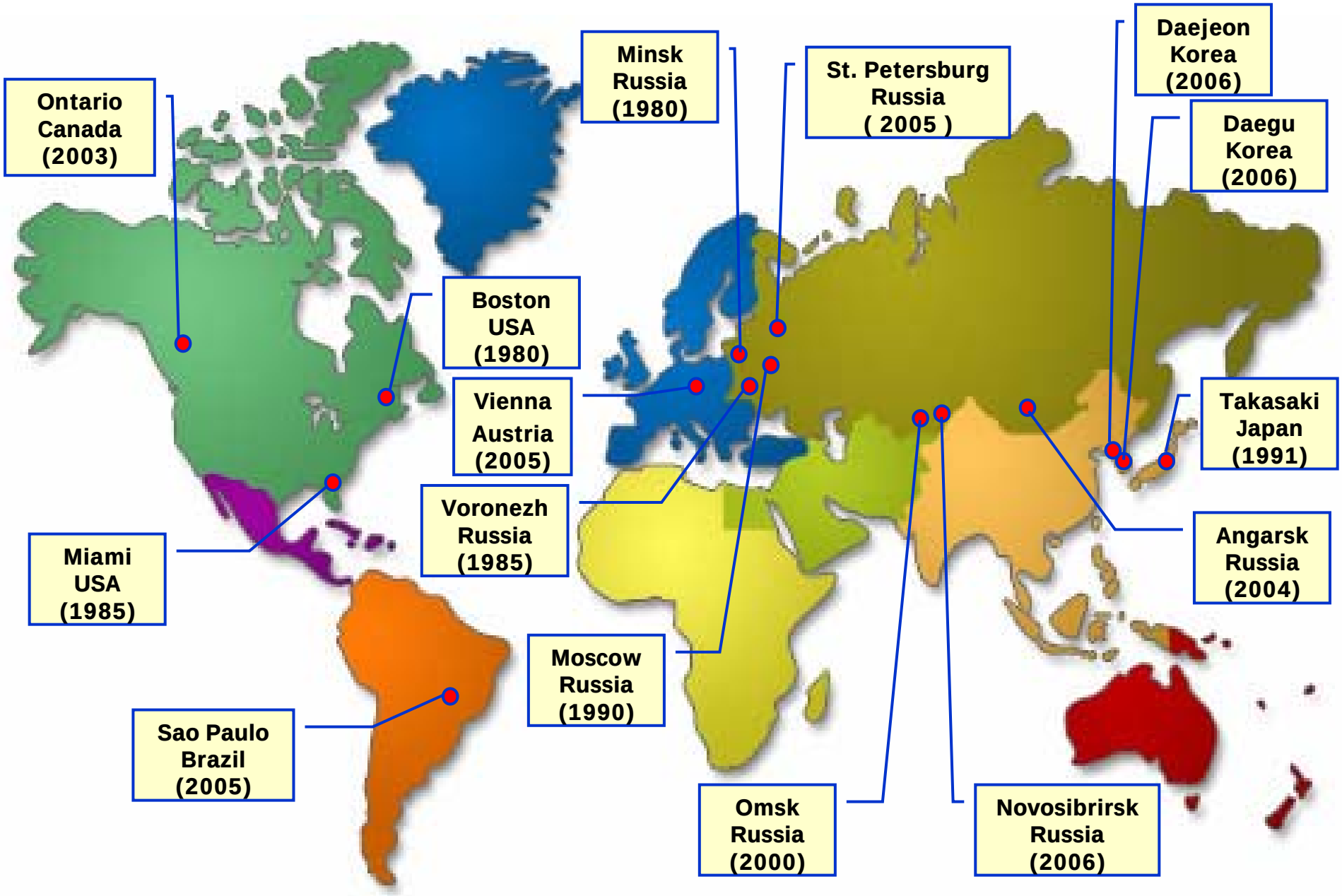

eBTECH

Application of e-beam on water/wastewater treatment



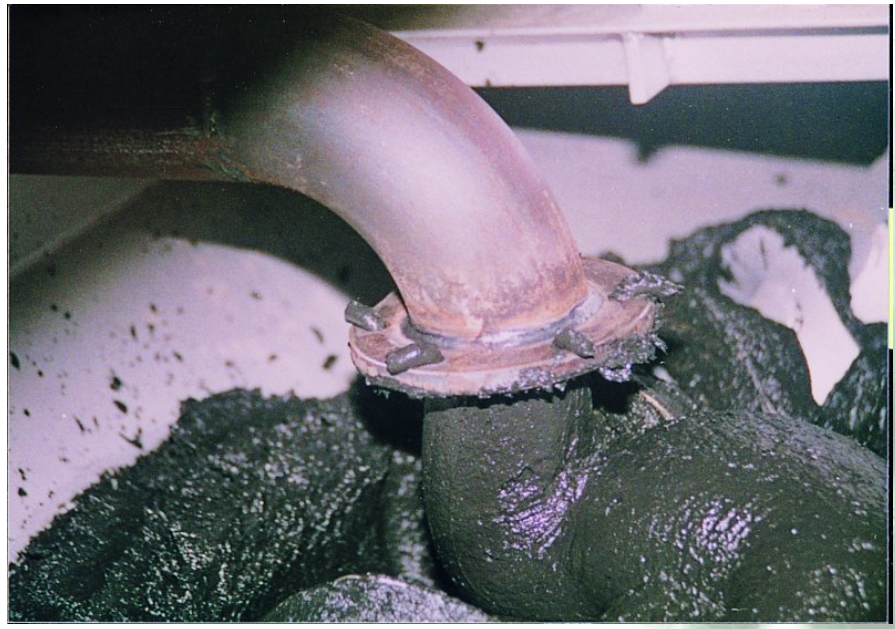
- -. Wastewater from Textile Dyeing Companies
- -. Wastewater from Papermill
- -. Leachate from Sanitary Landfill
- -. Wastewater containing Heavy metals (Cd,Hg,Pb,Cr^{+6})
- -. Re-use of effluent from municipal wastewater plant
- -. Remediation of contaminated water (PCB,Explosives)
- -. Contaminated Underground water
- -. Drinking water

Water/Wastewater treatment plant



Industrial Electron Beam Wastewater Treatment Plant in Daegu, Korea

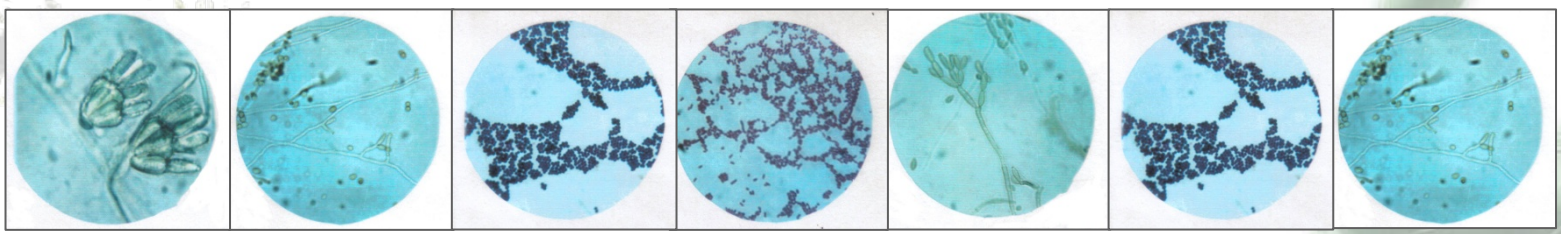
Sludge Hygenization



- The solid waste in sewage is typically organic in nature and is broken down in the sewage treatment plants resulting in sewage *sludge* as a byproduct.

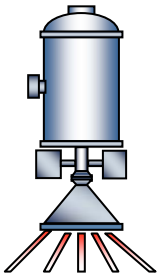
Typical pathogens present in sludge

Microorganism	Concentration per 100 ml
Coliforms	$10^7 – 10^9$
Fecal Coliforms	$10^6 – 10^8$
Fecal Streptococci	$10^6 – 10^7$
Salmonella	1 - 100
Anaerobic spore forming bacteria	



E- Beam Sludge Treatment

+. Sludge Hygienization



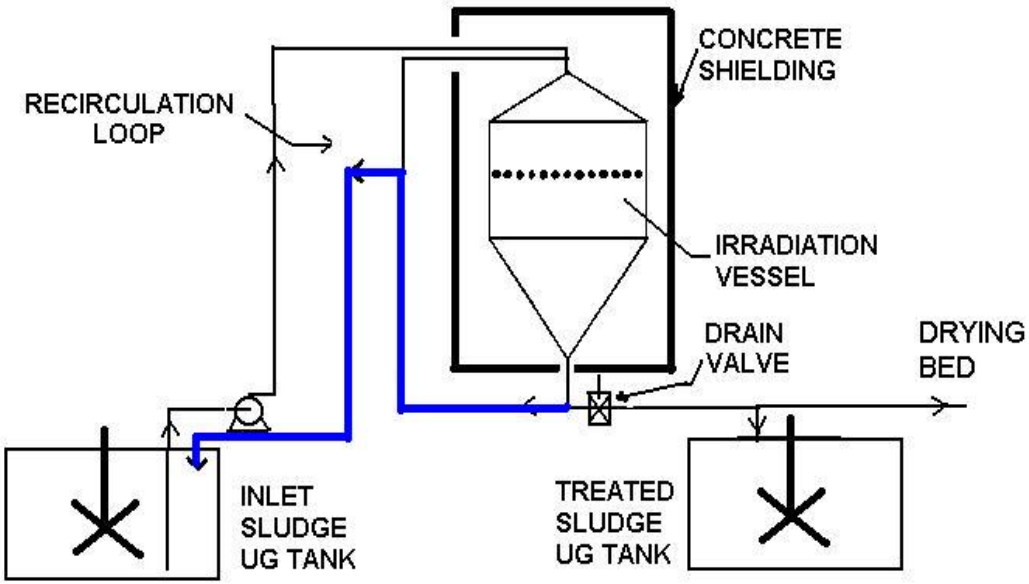
$H_2O \xrightarrow[\text{Radiation}]{} \bullet OH,\ H\bullet,\ e^-_{aq},\ H_2,\ H_2O_2$

$\bullet OH, H\bullet, e^-_{aq}$ + DNA of microorganism $\rightarrow$ Damage in DNA (no duplication)

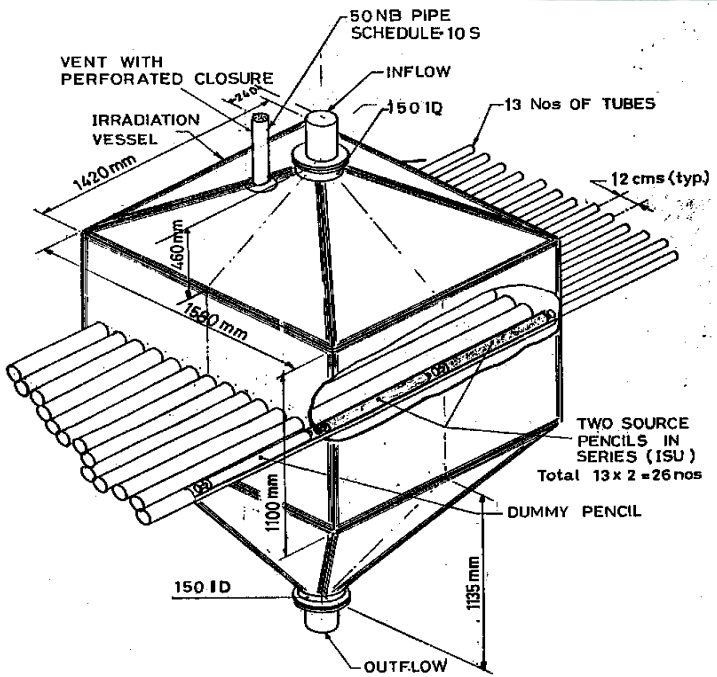
Pilot and Commercial Sludge Treatment Plants

Facilities	Irradiation Source	Irradiated material	Operation condition	Remarks
Munich, Germany (1973~1984)	Gamma-ray(60Co) 0.57Mci	Liquid Sewage sludge, 145m3/day	2-3kGy,	Commercial plant
New Maxico, USA (1978)	Gamma-ray(137Cs) 0.9MCi	Sewage sludge cake 22-90t/day	10kGy	Pilot Plant Conveyor
Vadodara, India (1989)	Gamma-ray(60Co) 0.5Mci	Liquid Sewage sludge, 110m^3/day(4%SS)	3-5kGy	Commercial plant
Tucuman, Argentina (1998)	Gamma-ray(60Co) 0.7Mci	Liquid Sewage sludge, 180m^3/day(8-10%SS)	3kGy	
Weldel, Germany (1980)	Electron beam 50kW(1.0MeV, 50mA)	Liquid Sewage sludge 500m^3/day	4kGy	Incline plan reactor
Verginia Key Florida, USA(1984)	Electron beam(ICT type) (75kW/1.5MeV/50mA)	Liquid Sewage sludge, 645m^3/hr, 4%ss	4kGy 10mm-thick	Pilot plant
Takasaki, Japan (1991)	Electron beam (Cockcroft-walton) (15kW/2MeV/15kW)	Sewage sludge cake 300kg/h	5kGy 1-10mm thick	Conveyor/Nozzle
Sao paulo, Brazil (1993)	Electron beam 25kW(1.5MeV, 25mA)	Liquid Sewage sludge 3m^3/hr	3kGy	Pilot Plant
Warsaw, Poland (1994)	Electron beam(LAE13/9) (10MeV, 15kW)	Sewage sludge cake, 70t/day	5-7kGy 2-3cm thick	Design Works
Daejeon, Korea (2005)	Electron beam 40kW(1.0MeV, 40mA)	Dewatered Sludge	1~3kGy 6mm thick	Pilot scale

Gamma ray Sludge Hygenization Process at India



RADIATION PROCESS -MODIFIED



THE SOURCE FRAME INSIDE THE IRRADIATOR


2006 3 14


2006 3 14


2006 3 13

Sewage Sludge Treatment (ISRAEL)

Why e-beam processes are not widely used ?

Barriers for Industrial Application

-. Public Acceptances
- Uneasy for the Radiation Safety
- New Species by Radiation

-. Technical problems
- Reliability for year-round operation
- Analysis of by-product, Toxicity

-. Regulation from Authorities

-. Competition with Other processes (Economics)
- Difficult to beat the conventional processes
- High investment cost and long returns
- No Alternatives or by-passes for shut-down
- Not universal for all environmental plant
- Difficult to find BP

-. Scaling up from Lab. to Industrial Implementation
- High cost for Pilot Plant Construction

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Radiation process (e-beam, γ-ray etc.) can survive only when it has **Technical & Economical advantages** over existing processes.

Radiation processing should be

Better & Cheaper

to other processes.

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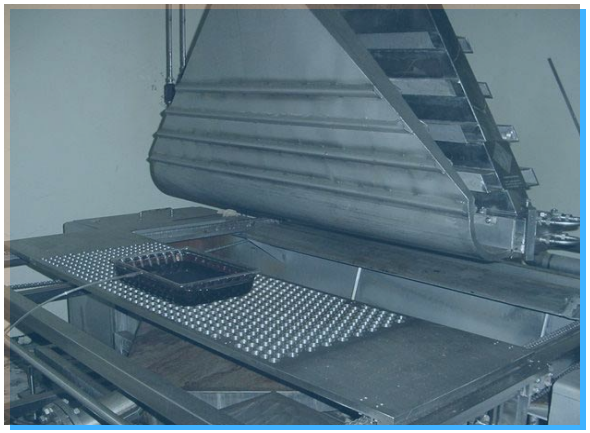
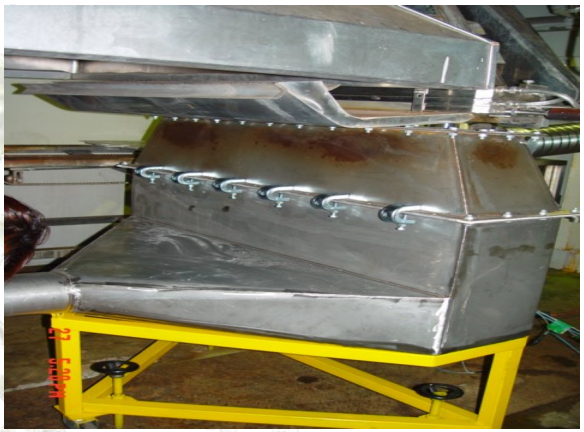
- **High cost for Pilot Plant Construction**

Lab. Scale Experiments (1~50m³/day)





Lab. Scale Experiments (1~10,000Nm³/h)

Pilot scale Experiments (500~1,000m³/day)

-. Cost
-. Space
-. O & M etc.

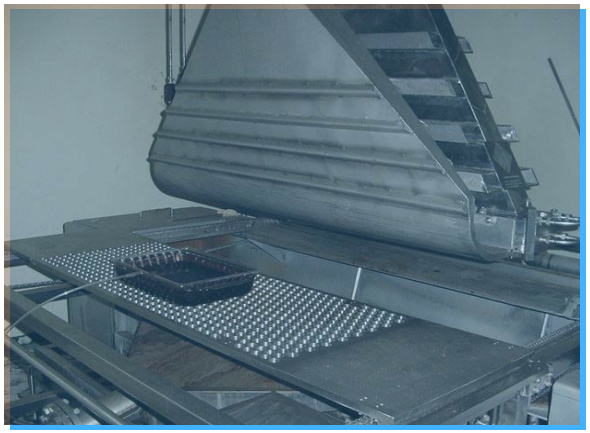
Industrial scale Wastewater Plant (10,000m³/day)

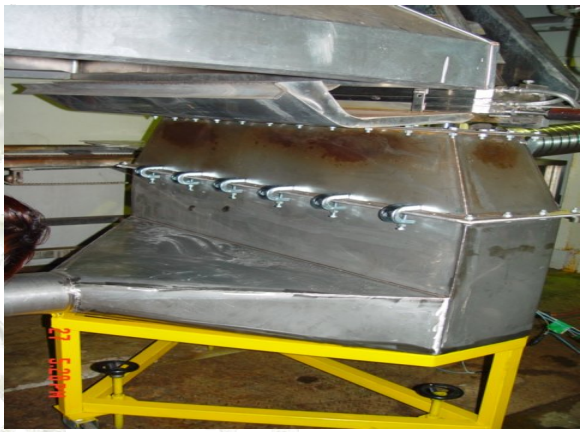
Industrial scale EBFGT Plant (~600,000Nm³/h)

Construction Cost for Pilot Plant

Type	Capacity	Main facility	Others	Total
Liquid	500~1,000m^3/d with 1~5kGy	accelerator (50kW) 0.7M$ shieldroom and Civil 0.4M$ reactor/piping etc. 0.2M$	reservoir 0.3M$ etc. 0.1M$	1.7M$
Gas	~20,000Nm^3/h with 4~8kGy	accelerator (50kW) 0.7M$ shieldroom and Civil 0.4M$ reactor/piping etc. 0.2M$	cooler 0.2M$ ESP 0.4M$ etc. 0.1M$	2.0M$
Sludge	10~20m^3/h with 10kGy	accelerator (50kW) 0.7M$ shieldroom and Civil 0.4M$	conveyor 0.1M$ feeder 0.3M$ piping etc. 0.2M$	1.7M$

Lab. Scale Experiments (1~50m³/day)





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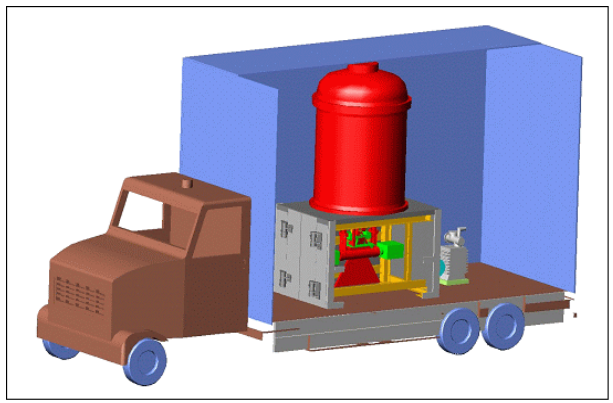
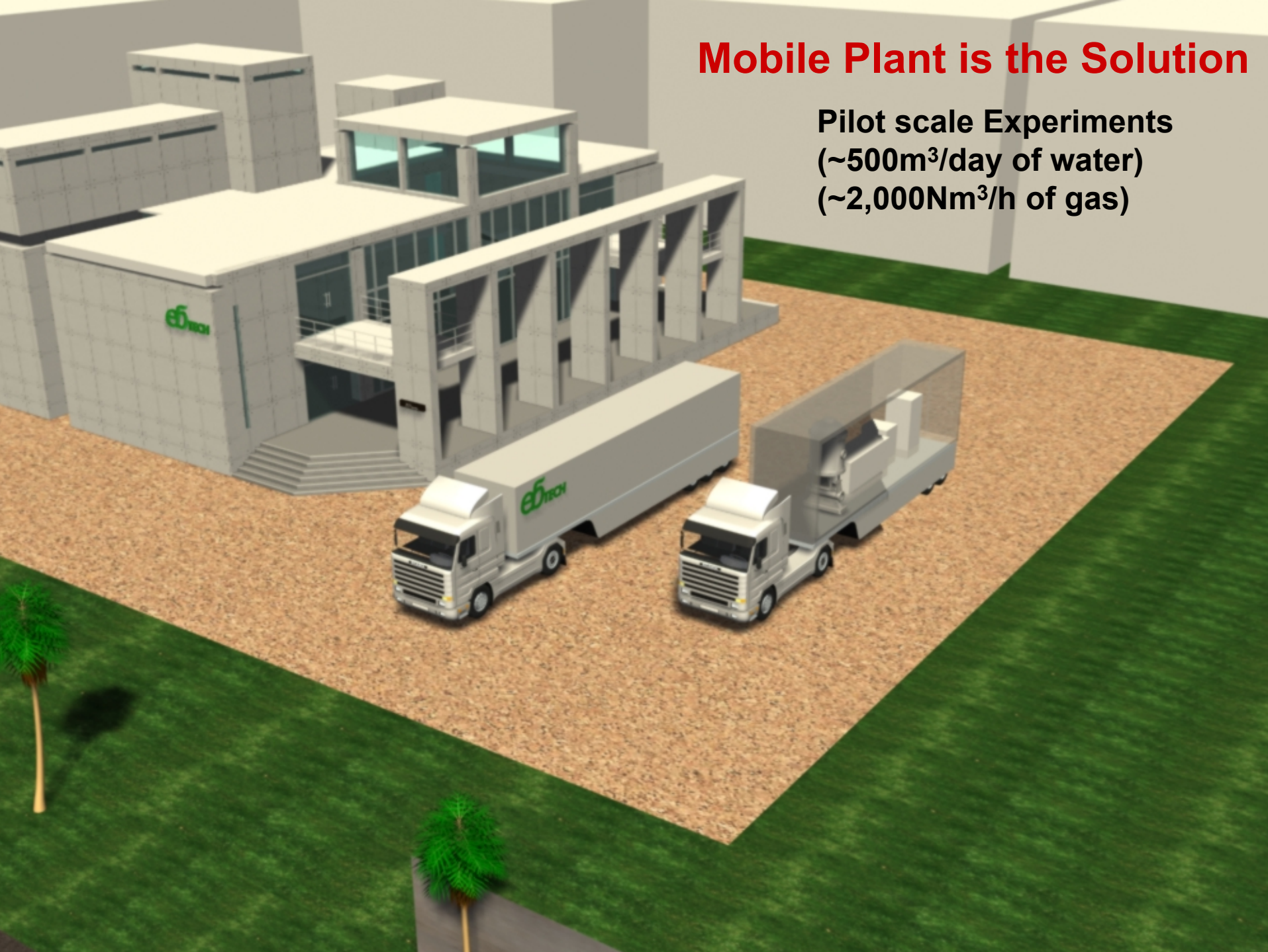
Pilot scale Experiments (500~1,000m³/day)



Industrial scale Wastewater Plant (10,000m³/day)

Industrial scale EBFGT Plant (~600,000Nm³/h)


Mobile Plant is the Solution
Pilot scale Experiments
(~500m3/day of water)
(~2,000Nm3/h of gas)

Requirements for Mobile Accelerator

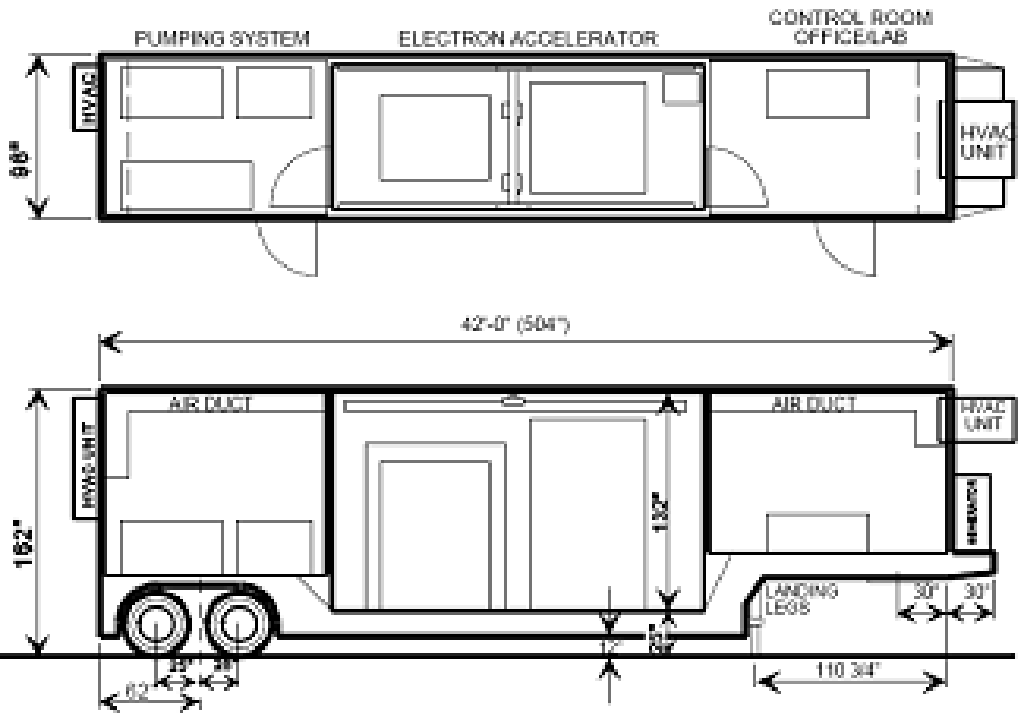
Size and weight : fit to the world standard
(less than 40 ft in length and 30 tons in weight)

Beam Energy : enough high to get some penetration in water
(higher than 0.6MeV)

Beam Power : enough high to work as a pilot scale
(over 200m^3/d of water, 1,000Nm^3/h of gas)

Safety : from the radiation, high voltage etc.
stable structure for transportation

Previous Mobile Accelerator (HVEA, U.S.A. 1990)



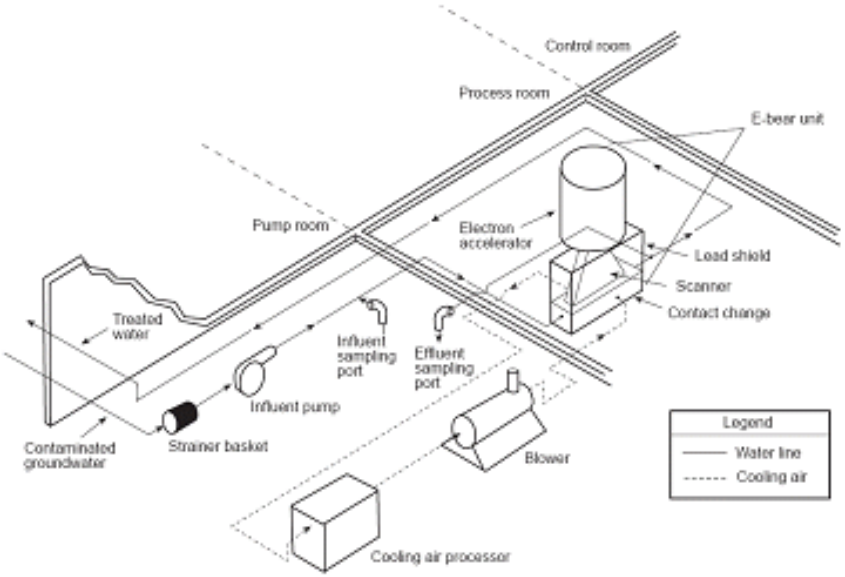
ICT accelerator

500 keV

0~40 mA

Max. 20kGy

for watsewater

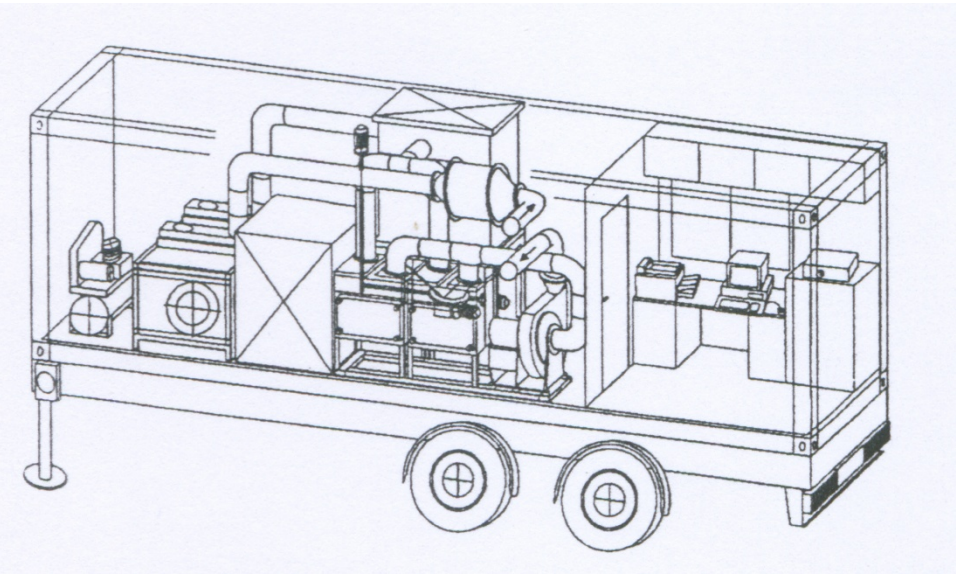


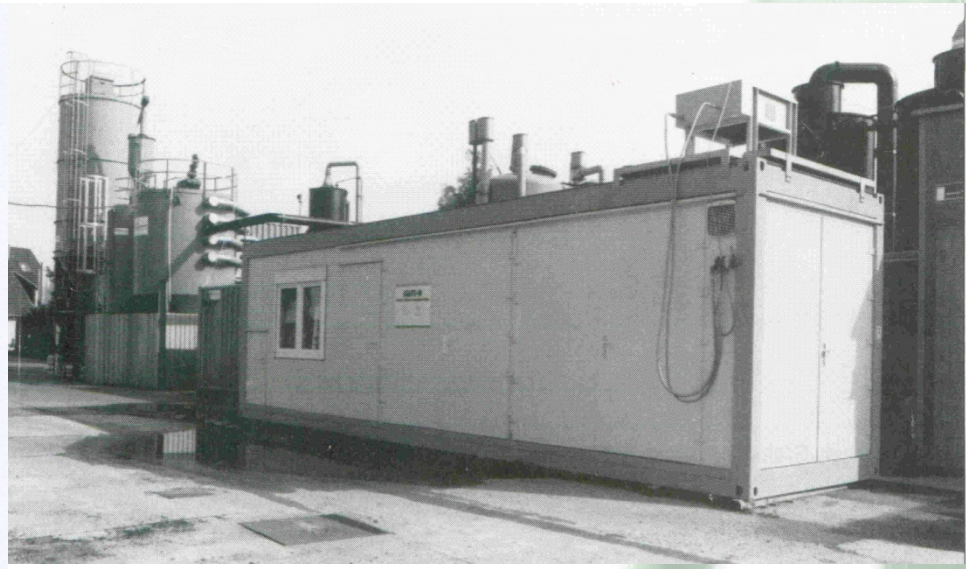
Ref.) Environmental Applications of Ionizing Radiation, Edited by william J. Cooper, Randy D. curry, and Kevin E. Oshea, "Field Application of a mobile 20-kW electron beam treatment system on contaminated groundwater and industrial wastes", p.451-466, ISBN 0-471-17086-0, 1998 John Wily & Sons, Inc.

Previous Mobile Accelerator (FZK, Germany 1984)

ESI Electrocurtain 200 keV, 0~150 mA

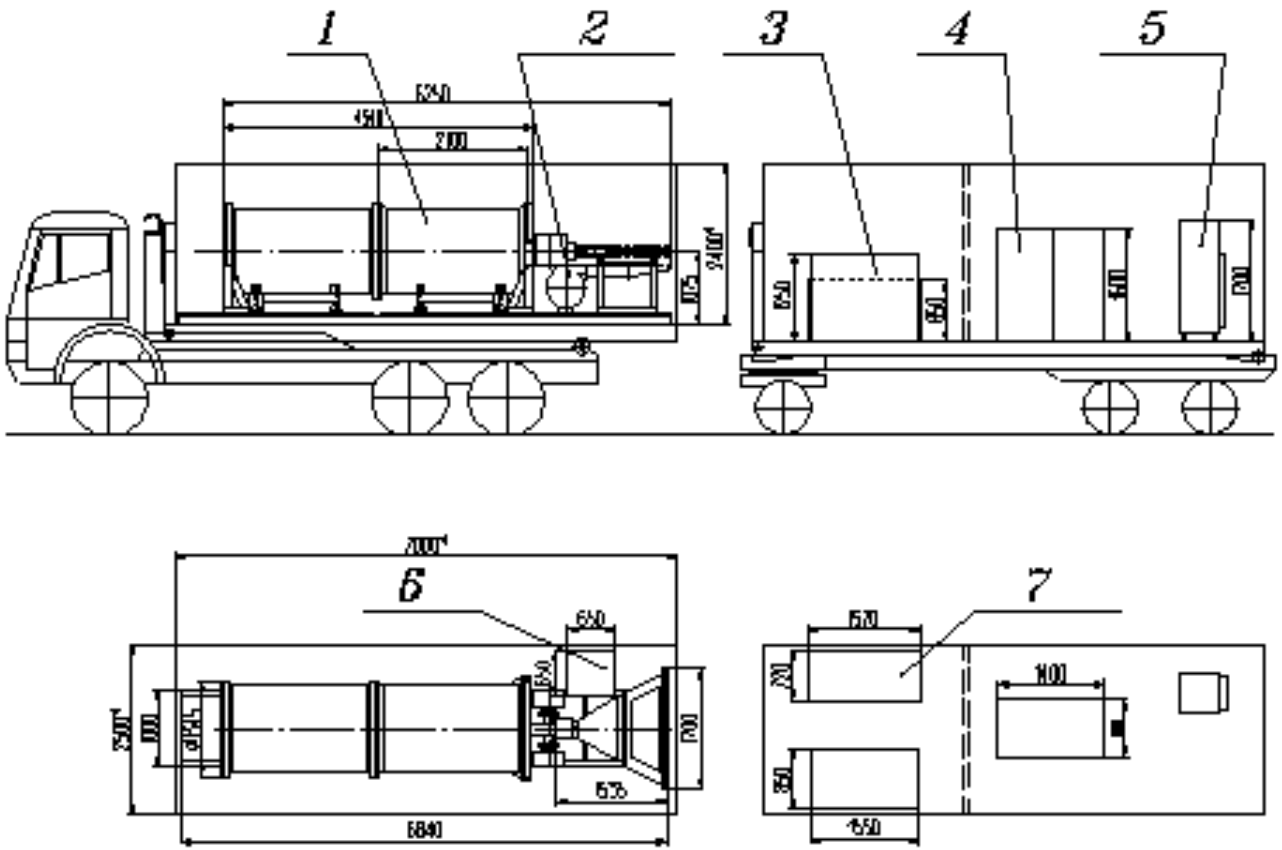
Flow rate : 1,000Nm³/h for gas treatment



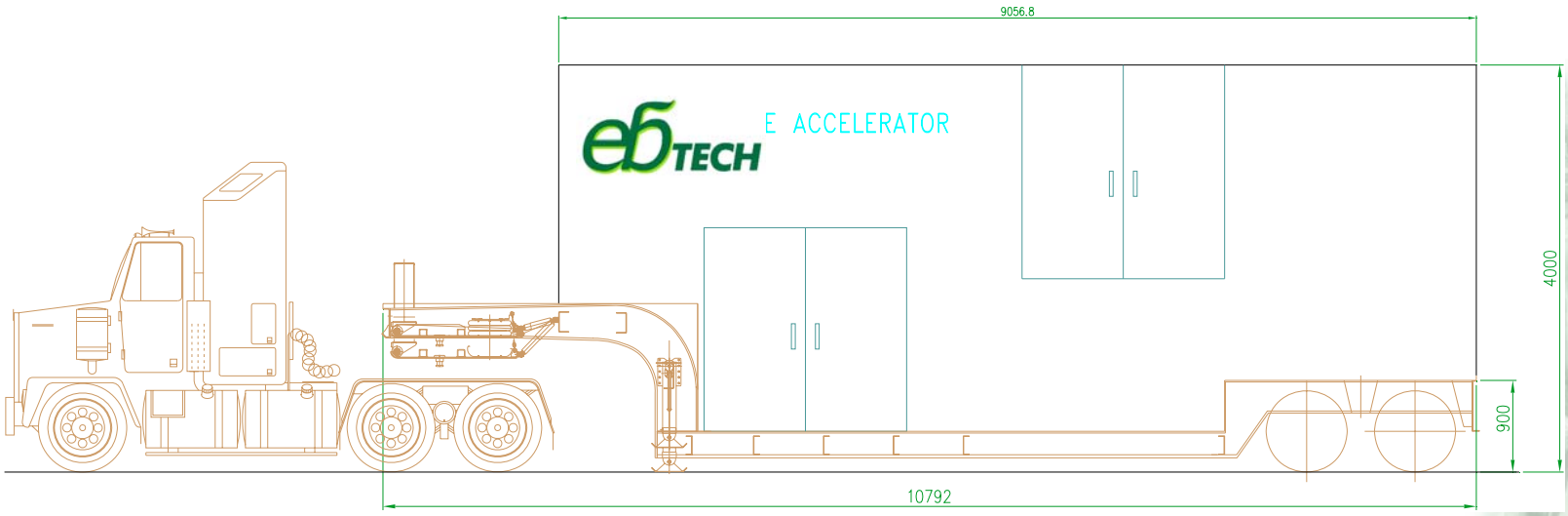


Ref.) FUCH, P.; ROTH B.; SCHWING, U.; ANGELE, H.; GOTTSTEIN, J. Removal of NOx and SO2 by the electron beam Process. Radiation Physics and Chemistry, 31, No. 1-3,(1988) 45-56

Previous Mobile Accelerator (BINP, Russia design)



Ref.) VESTNIK “RADTECH-EUROASIA”, Edited by S.I.Suminov “Accelerators of ELV type : Status, Development, Applications” pp6~15 Novosibirsk, 1999



Beam Energy : 0.4~0.7MeV, Beam Power : 20kW

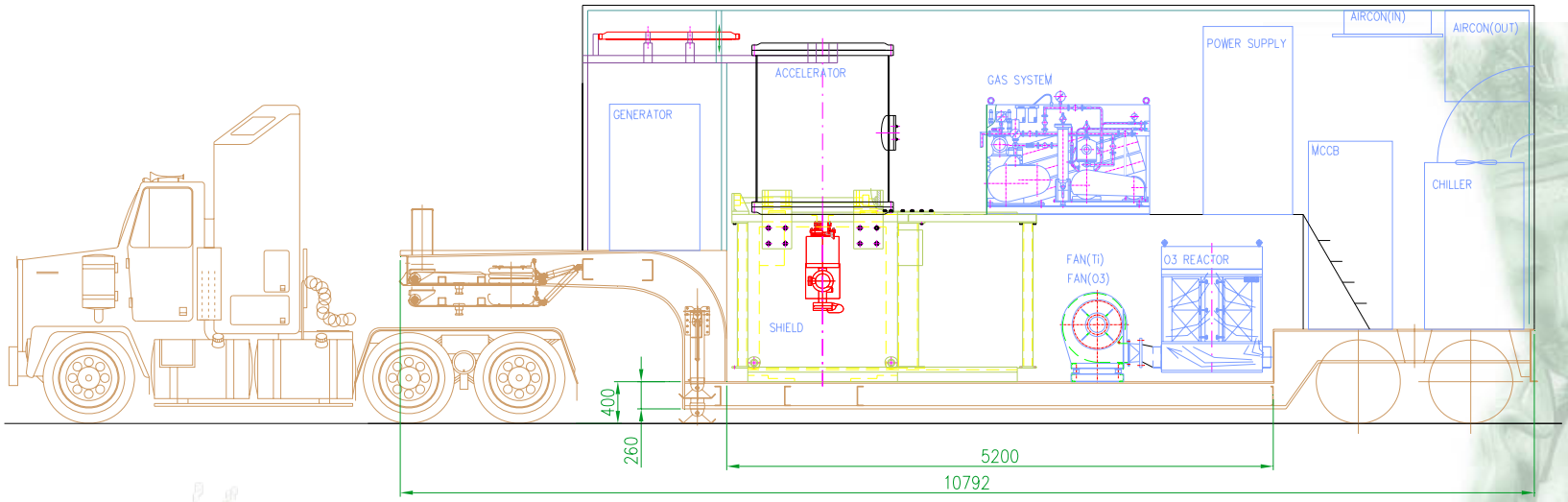
Self-sustaining system : Self-shielded accelerator

Built-in control and monitoring room

Diesel electricity generator (option)

Trailer and Shelter : Fit to U.S. and world standard

Total weight : 40 tons (trailer only 30ton)

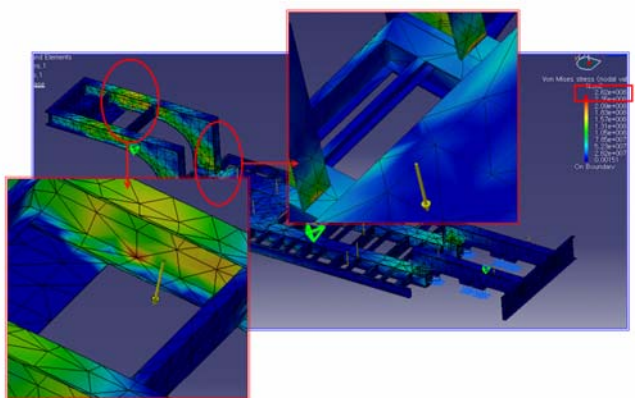


Built-in Computerized Experimental & Monitoring System

Continuous Treatment of Wastewater/Flue gas on site

Treatment Capacity : Liquid waste : 500m^3/day (at max. 2kGy)

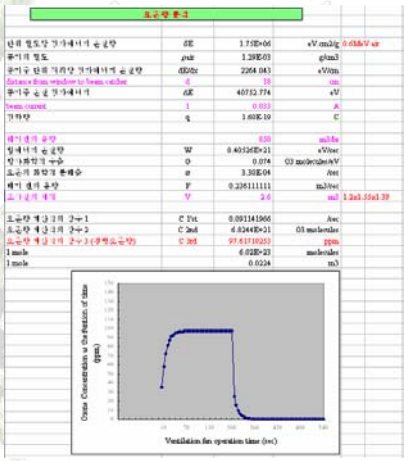
Gaseous waste : 2,000Nm^3/h (at max. 15kGy)



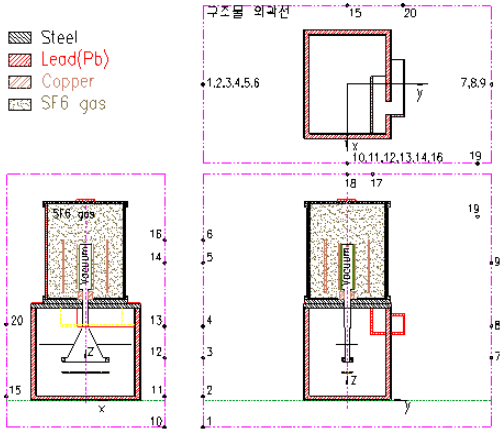
Structure stress simulation

fluid calculation

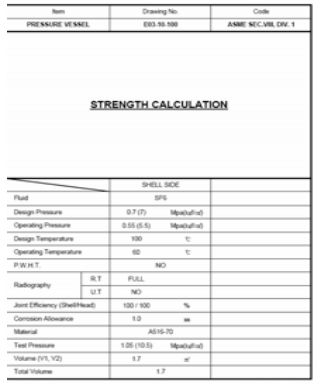
Heat & Cooling calculation



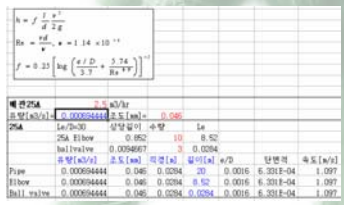
Ozone simulation



MCNP shielding calculation

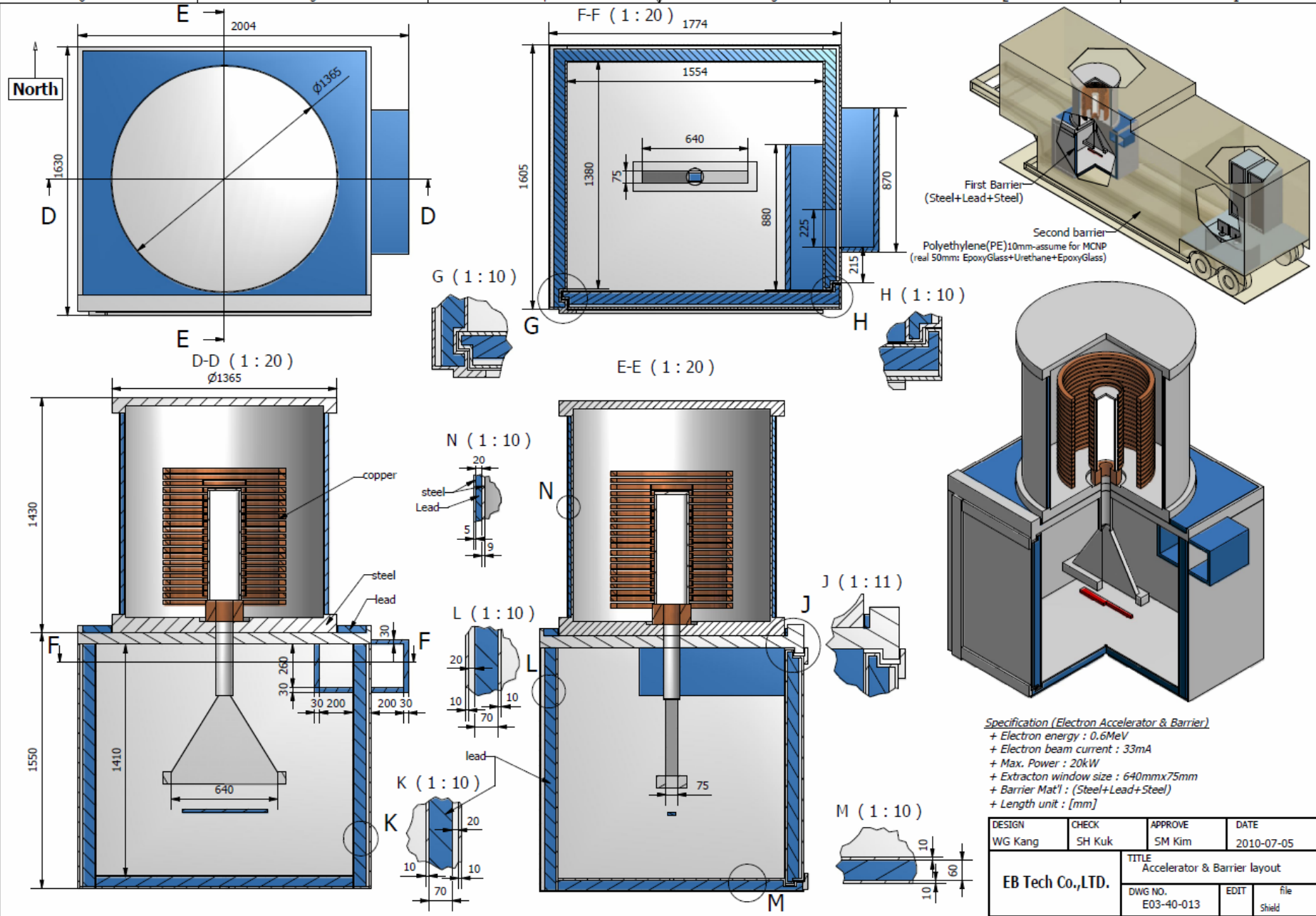


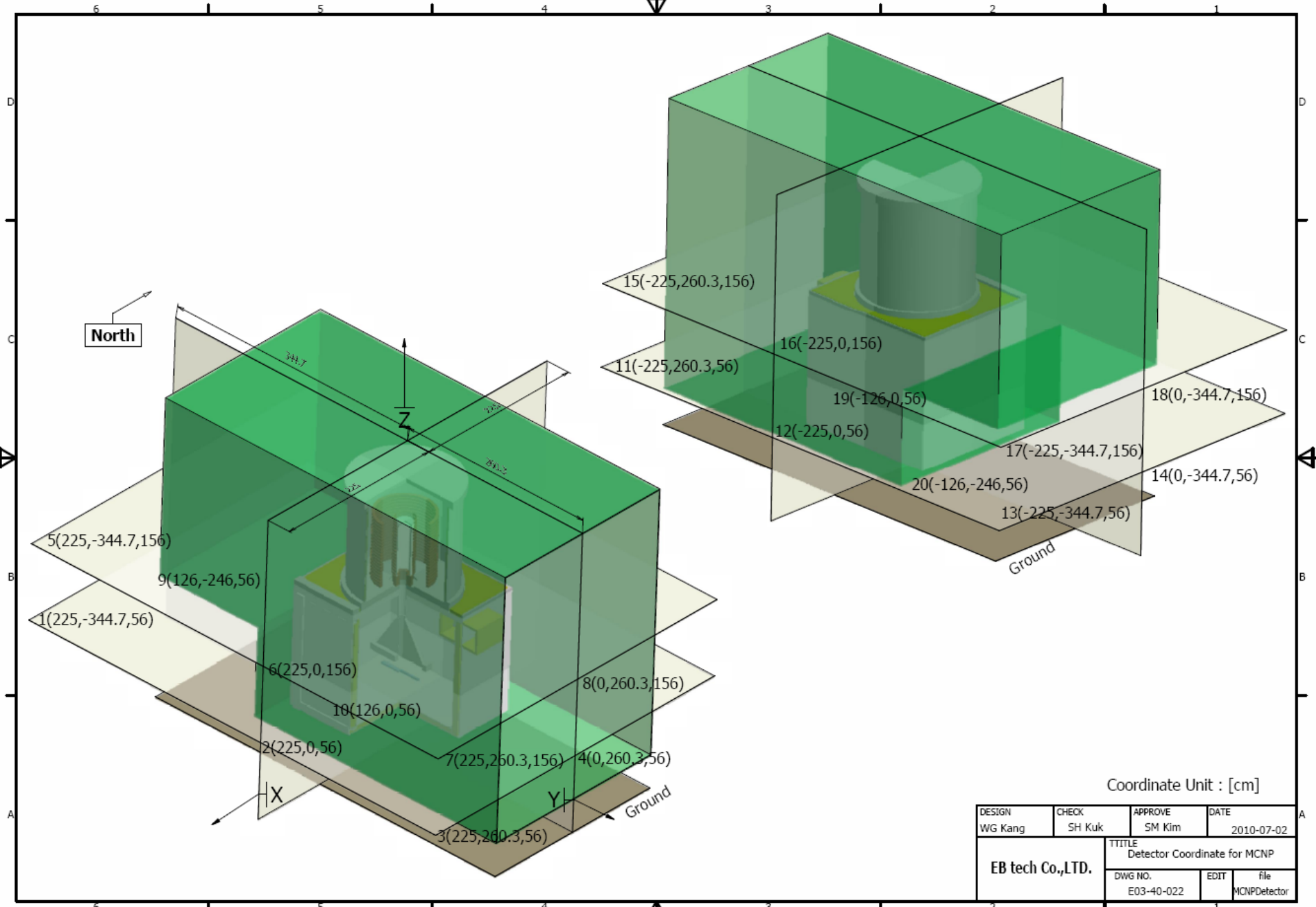
Vessel ASME

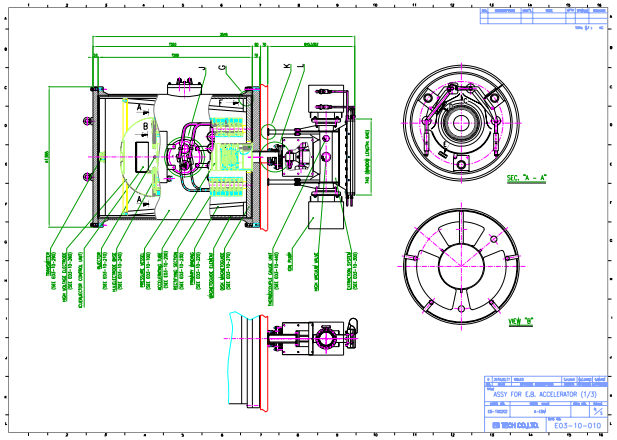


ETC

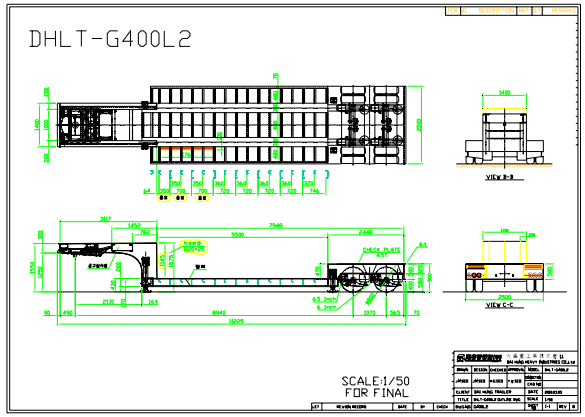
-.Radiation leakage calculation under ICRP with MCNP (Monte Carlo) Simulation



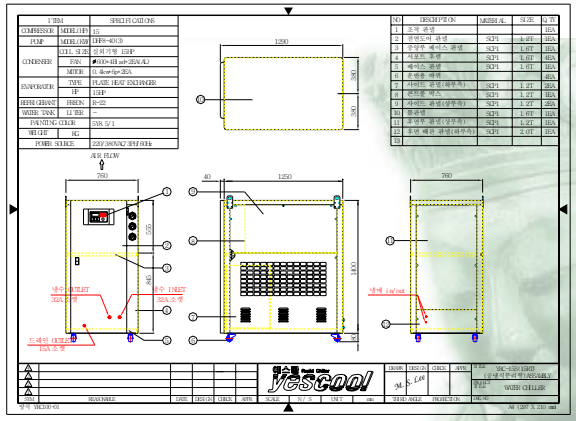

North
Z
X
Y
5(225,-344.7,156)
9(126,-246,56)
1(225,-344.7,56)
6(225,0,156)
10(126,0,56)
2(225,0,56)
8(0,260.3,156)
7(225,260.3,156)
4(0,260.3,56)
3(225,260.3,56)
Ground
15(-225,260.3,156)
16(-225,0,156)
11(-225,260.3,56)
19(-126,0,56)
12(-225,0,56)
18(0,-344.7,156)
17(-225,-344.7,156)
14(0,-344.7,56)
20(-126,-246,56)
13(-225,-344.7,56)
Ground
Coordinate Unit : [cm]
DESIGN WG Kang
CHECK SH Kuk
APPROVE SM Kim
DATE 2010-07-02
EB tech Co.,LTD.
TTITLE Detector Coordinate for MCNP
DWG NO. E03-40-022
EDIT
file MCNPDetector



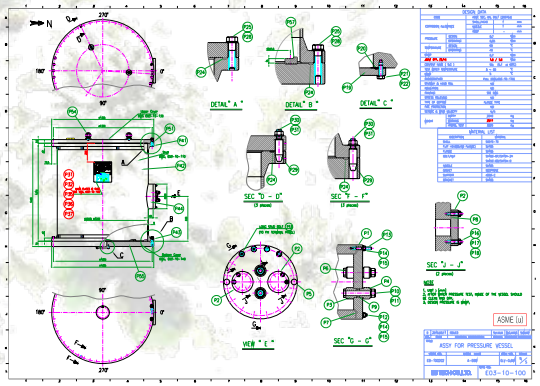
Accelerator



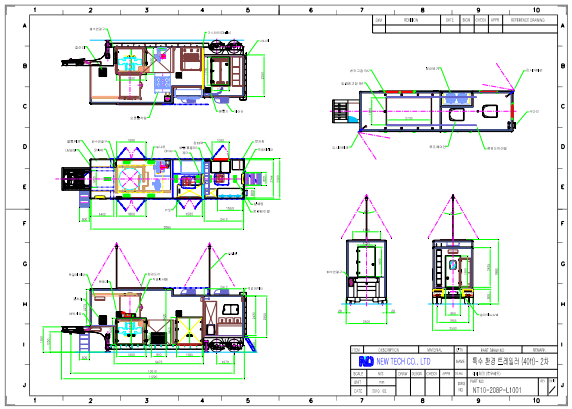
Trailer



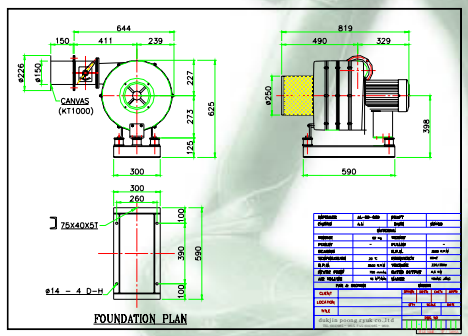
chiller



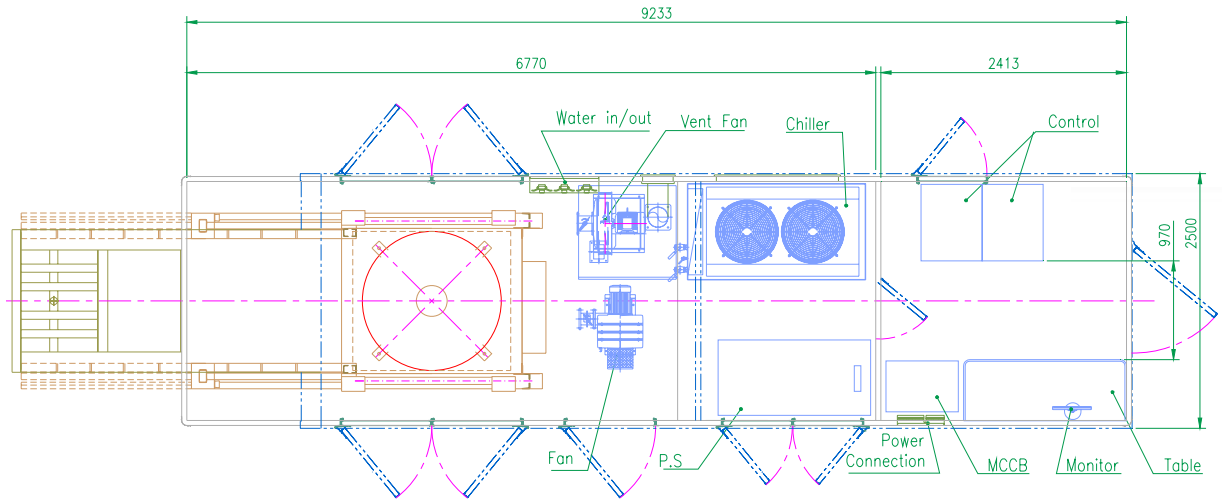
Vessel

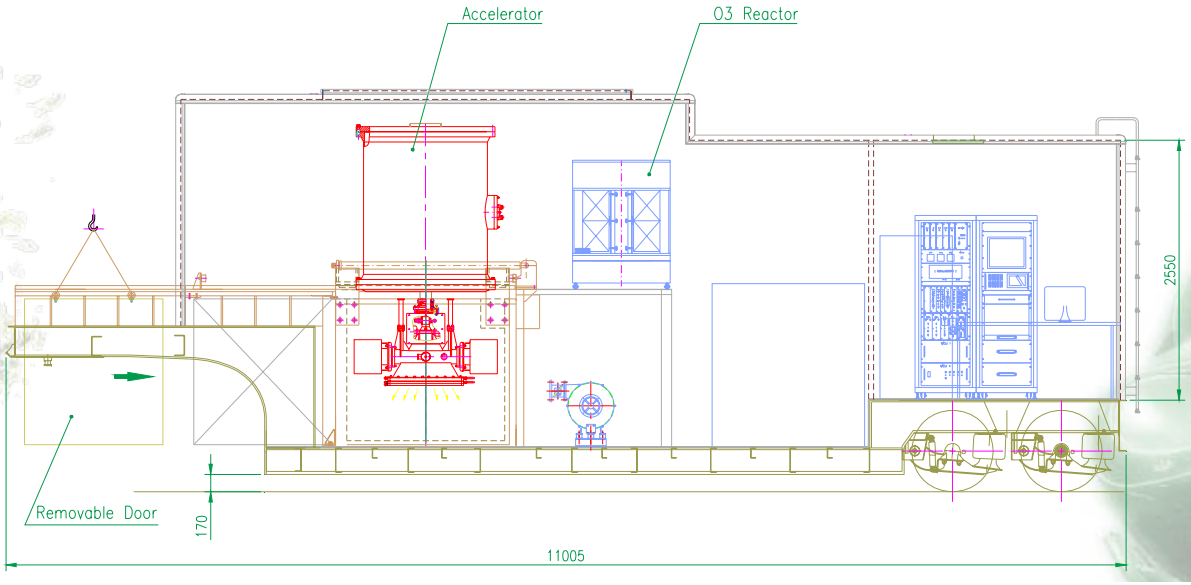


Shelter



Fan & ETC


9233
6770
2413
Water in/out
Vent Fan
Chiller
Control
970
2500
Fan
P.S
Power Connection
MCCB
Monitor
Table


Accelerator
03 Reactor
2550
Removable Door
170
11005




Trailer

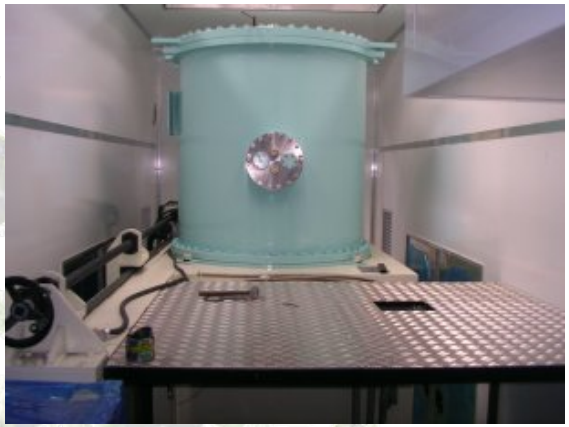


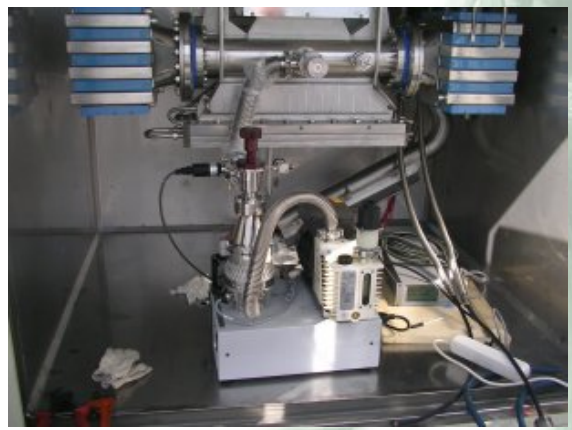
Vessel

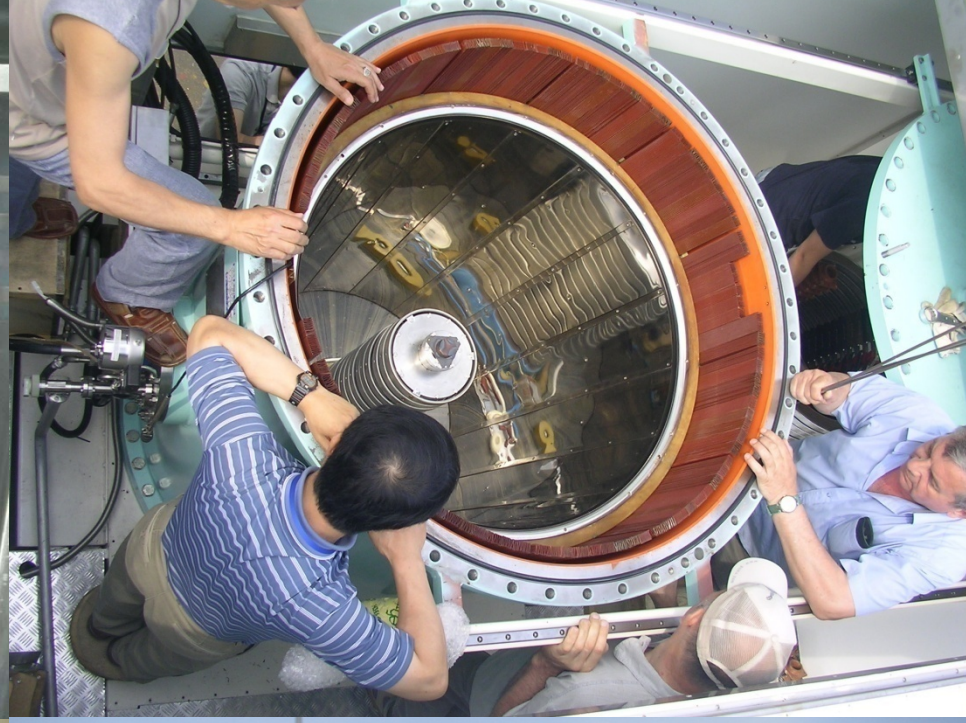

Shield

Shelter

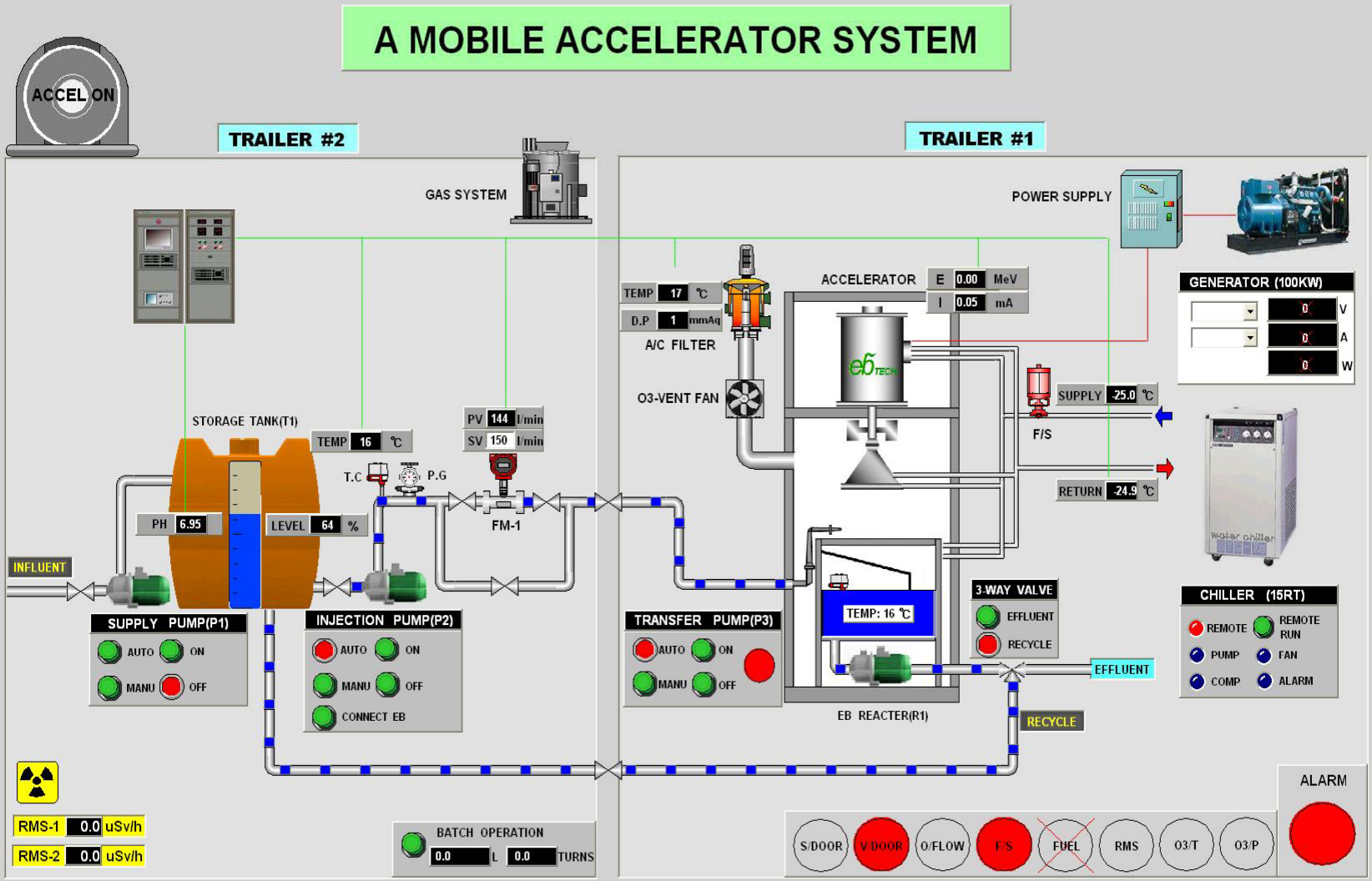







PELE TECHNOLOGY, INC.
PELE TECHNOLOGY, INC.
Mobile Electron Accelerator
BEAM ON


DAQFactory Runtime
A MOBILE ACCELERATOR SYSTEM
ACCEL ON
TRAILER #2
TRAILER #1
GAS SYSTEM
POWER SUPPLY
GENERATOR (100KW)
V
A
W
ACCELERATOR
E 0.00 MeV
I 0.05 mA
TEMP 17 ℃
D.P 1 mmAq
A/C FILTER
O3-VENT FAN
SUPPLY -25.0 ℃
F/S
RETURN -24.9 ℃
STORAGE TANK(T1)
TEMP 16 ℃
T.C
P.G
PV 144 l/min
SV 150 l/min
FM-1
PH 6.95
LEVEL 64 %
INFLUENT
SUPPLY PUMP(P1)
AUTO
ON
MANU
OFF
INJECTION PUMP(P2)
CONNECT EB
TRANSFER PUMP(P3)
TEMP: 16 ℃
3-WAY VALVE
EFFLUENT
RECYCLE
CHILLER (15RT)
REMOTE
REMOTE RUN
PUMP
FAN
COMP
ALARM
EB REACTER(R1)
RECYCLE
RMS-1 0.0 uSv/h
RMS-2 0.0 uSv/h
BATCH OPERATION
0.0 L 0.0 TURNS
S/DOOR
V/DOOR
O/FLOW
F/S
FUEL
RMS
O3/T
O3/P
ALARM

Mobile e-beam in Flue gas Purification from oil-refinery in Saudi Arabia

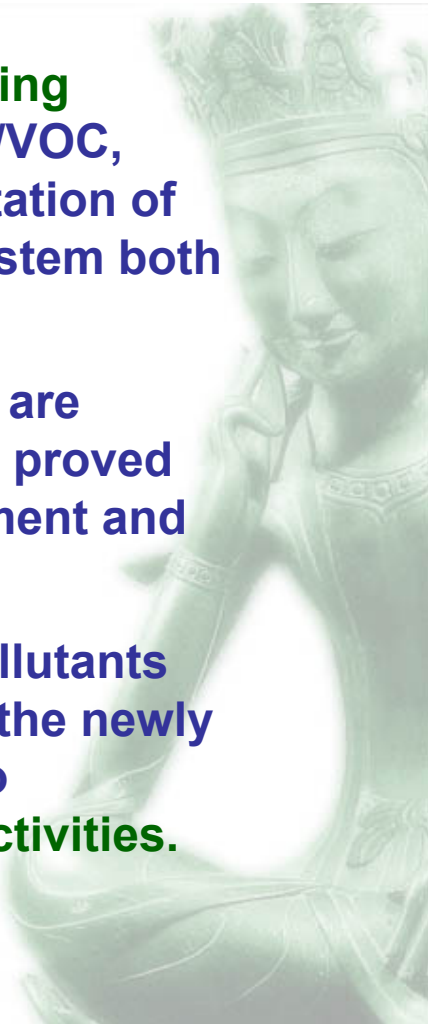
XXIII RUSSIAN PARTICLE ACCELERATORS CONFERENCE RuPAC-2012

September 24 – 28, 2012, St. Petersburg, Russia

Mobile e-beam in Flue gas Purification from oil-refinery in Saudi Arabia

5. Summary

1. **Electron Beam Technology has been one of the promising process for environmental treatment, such as Flue gas/VOC, Water/ Wastewater, and Sludge from 1970s. Implementation of large scale plant has demonstrated the efficiency of system both in technically and economically.**
2. **Accelerators of high power (several hundreds kilowatt) are already available in the market, and some of them have proved their reliability in long term operation in Flue gas treatment and Wastewater treatment.**
3. **The application of electron beam to the treatment of pollutants has emerged as one of effective methods and some of the newly developed electron beam technologies could be able to contribute to treatment of pollutants from the human activities.**




Thank You !