A Satellite Meeting at SRF 2011

The 2nd workshop on SCRF Cavity Technology and Industrialization for the ILC

Study of Industrialization and Factory Layout for SCRF Cavity Production

S.Ishii (Mitsubishi Heavy Industries)

in cooperation with KEK

SRF 2011 Satellite Meeting, Chicago,
July 24, 2011

Model for cavity mass production and evaluation

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- 9-cell cavity production models for ILC
  - 15,764 + spare + production back-up (~ 10%) = 17,000 cavities
  - 17,000 cavities / 5 factories = ~ 3400 cavities / 6 years
    = ~ 600 cavities / year / factory
- Previous study at IPAC10 in Kyoto showed 600 cavities/year production would require 4 EB welding machines
- This study is for factory layout and production capabilities assuming existing KEK building with more advanced production model
  - Cavity production process model and required time were provided by KEK.
  - Factory production simulation analyzed manufacturing model and required facilities, especially on EB welding process and defect inspection & repair.
  - All end-group parts assumed to be supplied as finished parts from outside supplier, and only EB welding process was evaluated.
  - Bulk EP and jacketing are included, however final EP and vertical test will be done outside of this factory.

Example of cavity fabrication process (1/2)

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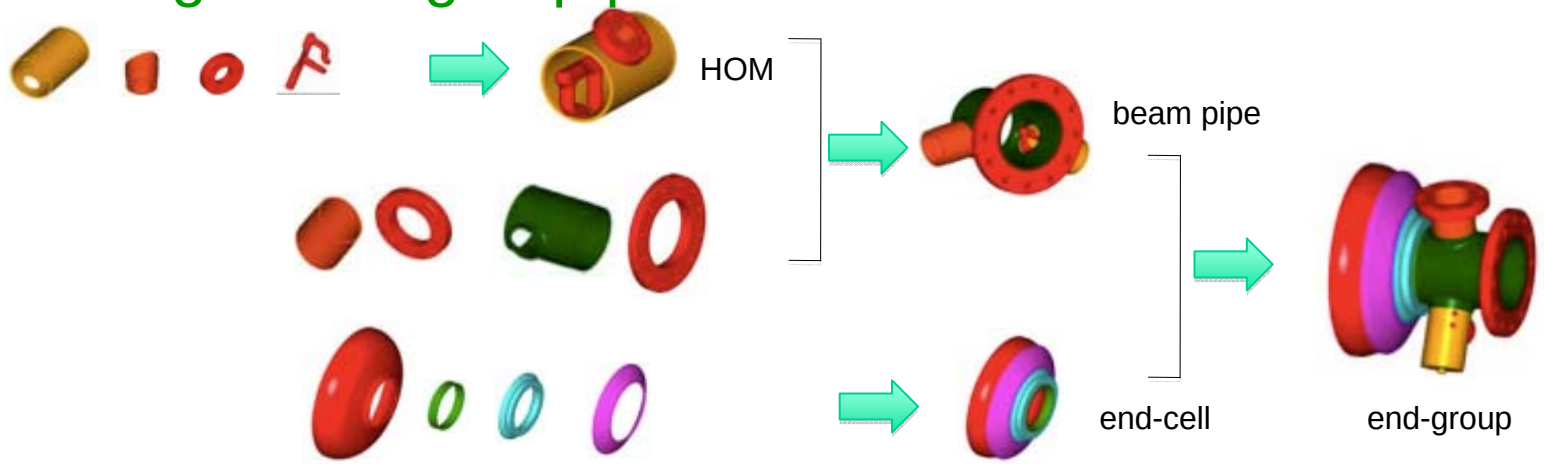
EB welding of dumb-bell

EB welding of end-group parts



- All end-group parts assumed to be supplied as finished parts from outside supplier in the simulation.

Example of cavity fabrication process (2/2)

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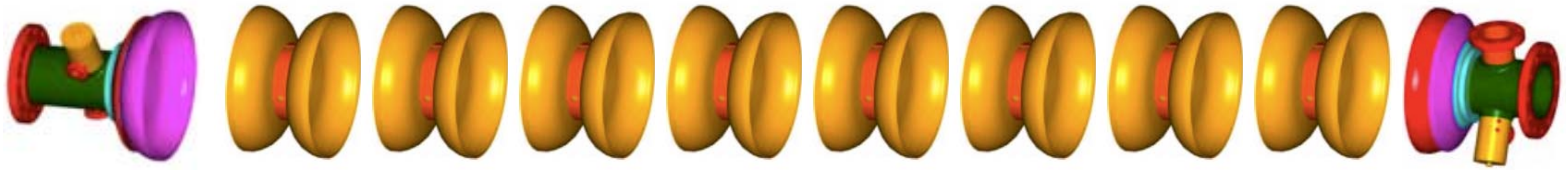
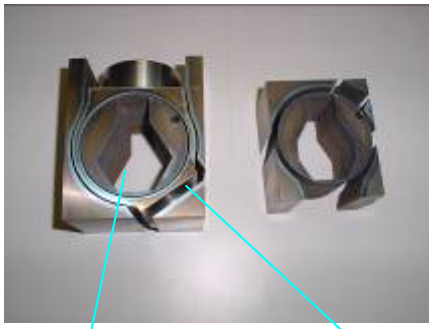
EB welding of 9-cell cavity



Welding of Ti helium jacket

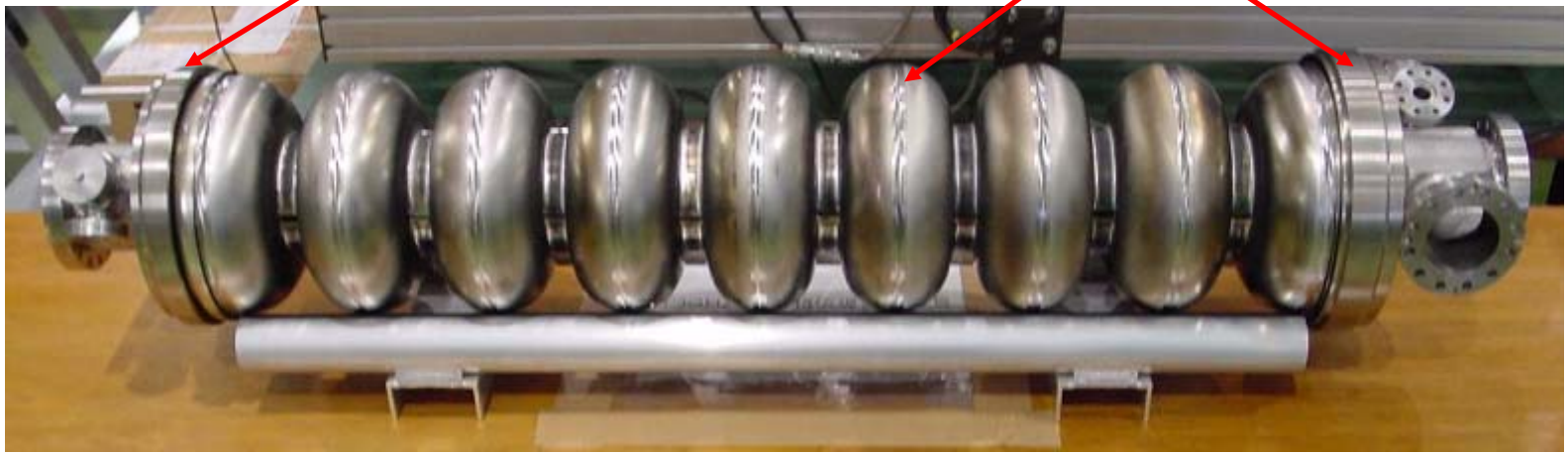
Cavity Fabrication Process



HOM coupler

End-groups

Center-cells
(Tokyo Denkai ; RRR~300 Nb)



Factory production simulation analysis

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- We evaluate an **ideal production factory** for cavity fabrication, cavity surface treatment, and jacket welding to manufacture about **600 cavities per year** by using a factory production simulation code.

[assumption]

- **KEK's R&D facility (52.5m X 29.5m)** was assumed for factory floor space.
- Revisit process time, preparing time to machining, welding, surface treatment and also manpower, including time for conveying parts and assemblies.
- **Throughput 95% at dumb-bell first inspection** and **80% at 9-cell cavity first inspection** are assumed. All defects could be repaired by using KEK's local grinding machine to yield 100%.
- Based on **16 hours of actual work time (2 shifts) per day** for man work, machining, and process.
- Production simulation code evaluates the number of machines and apparatus to satisfy the production rate.
- **Special jigs to handle multiple subassemblies** are assumed for machining, welding and other process for a given process cycle.
- End-group parts would be supplied as finished parts and **Nb sheets and end-group parts are stocked enough**.

Cavity mass production models

- Case 1（previous study: IPAC10）
  - Laboratory R&D scheme
  - 1 seam / one welding cycle
- Case 2（previous study: IPAC10）
  - Current production scheme at some industries
  - Dumb-bell: 8 seams / one welding cycle
  - 1 x 9-cell cavity EBW /one welding cycle
- Case 3（previous study: IPAC10）
  - Simple mass production model
  - Dumb-bell: 8 seams / one welding cycle
  - 8 end-group / one welding cycle
  - 1 x 9-cell cavity EBW /one welding cycle
- **Case 4（this study）**
  - **8 dumb-bell: 8 seams / 2 welding cycle**
  - **12 end-group / 7 welding cycles**
  - **4 x 9-cell cavity EBW / one welding cycle**

Mass Production Models (previous study)

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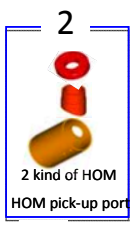
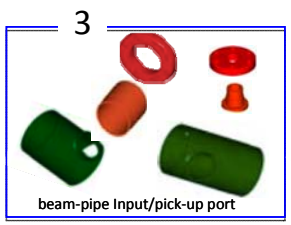
	Yield %	Fabrication of Dumb-bell with EBW	Fabrication of End-group EBW	Assemble 9-cell Cavity With EBW	Number of machines required EB Welding
Case1 R&D phase	100	1 seam / welding cycle (3 hrs/3 cycle)	1 seam / welding cycle (11 hrs / 11 cycle)	one 2(4,8)-cell / welding cycle (9 hrs/9 cycle)	**12**
	90				
Case2 Current production	100	8 dumb-bell / welding cycle (6.5/8 hrs/3 cycle)		one 9-cell / 2 welding cycle (4.7 hrs / 2 cycle)	**8 → 7***
	90				
Case3 Mass Production Study	100		8 end-group / welding cycle (46.7/8 hrs/11 cycle)		**5 → 4***
	90				
Case4 Mass Production Study	**100**	**8 dumb-bell / 2 welding cycle (6.7/8 hrs)**	**12 end-group / 7 welding cycles (15.2/12 hrs)**	**4 one 9-cell / 2 welding cycle (7/4 hrs)**	**2****

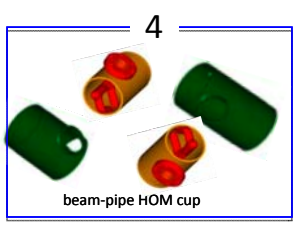
***In case of common EBW machines for dumb-bell and end-group**
****In case of common EBW machines for dumb-bell, end-group, and 9-cell**

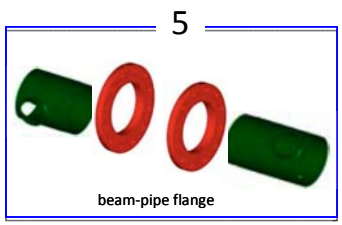
Example: End-groups EB Welding jig

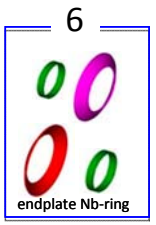
- Conceptual drawings of EBW jig provided by Prof. Hayano (KEK)

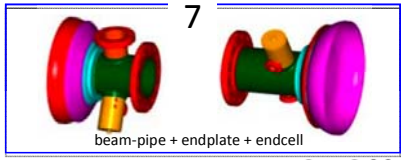






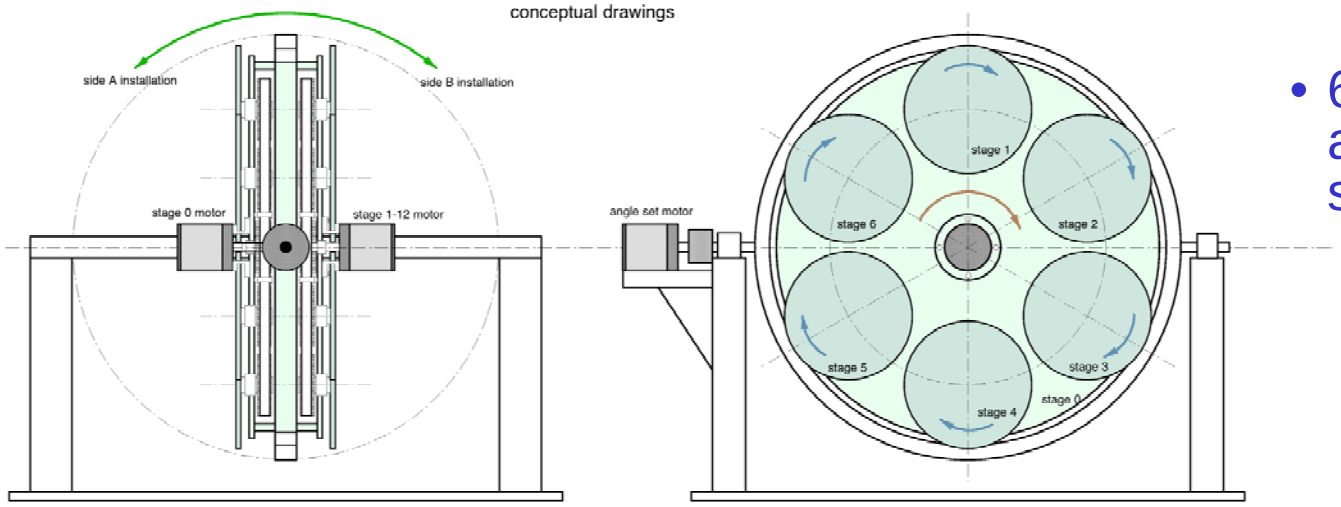






7 steps for End-groups parts EBW by one rotational stage jig

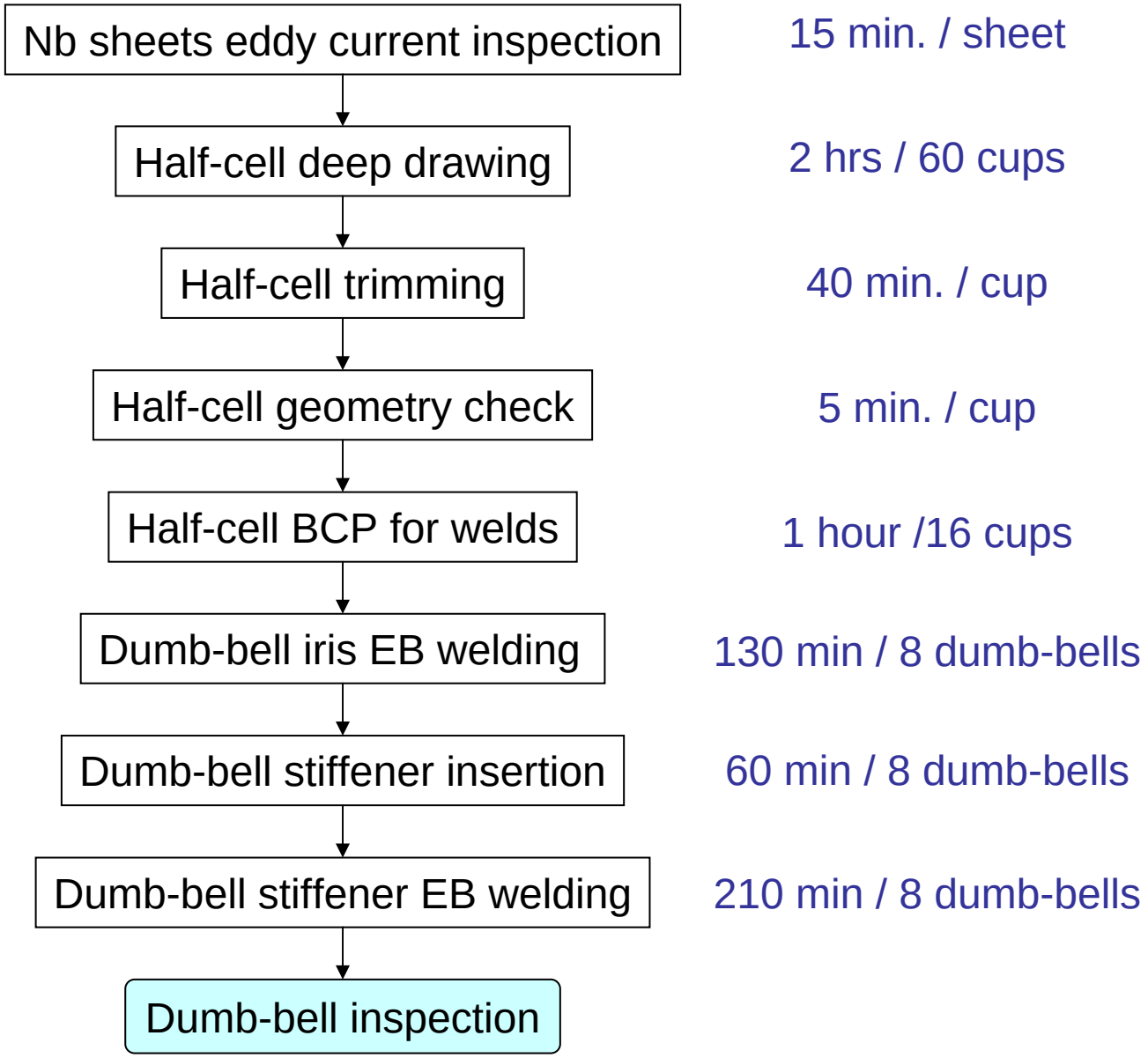
6 + 6 Multi-rotational Table for EBW (Dumbbell, endgroup parts)



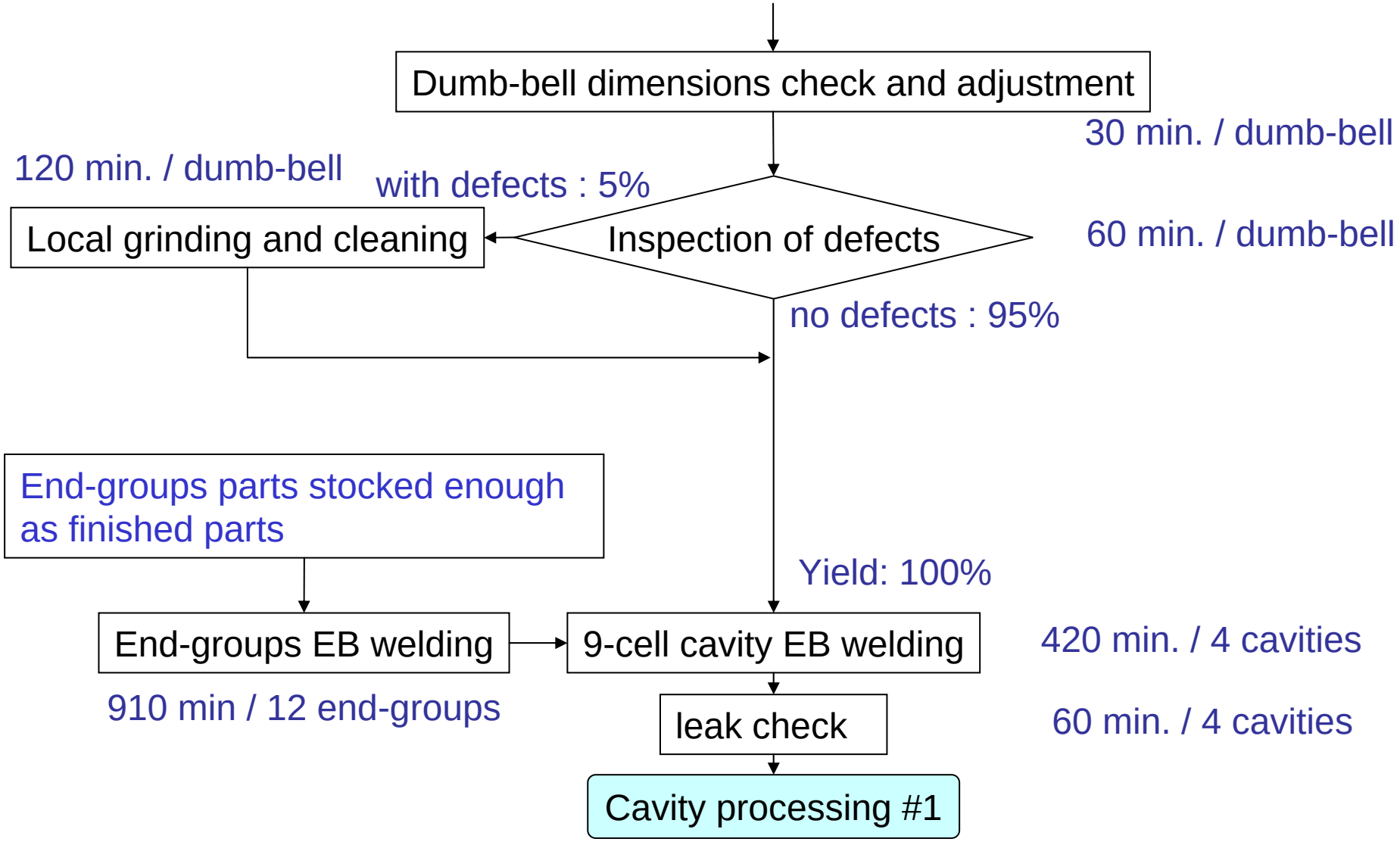
- 6 end-group parts are fixed at both side, total 12

Cavity fabrication process (1/2)

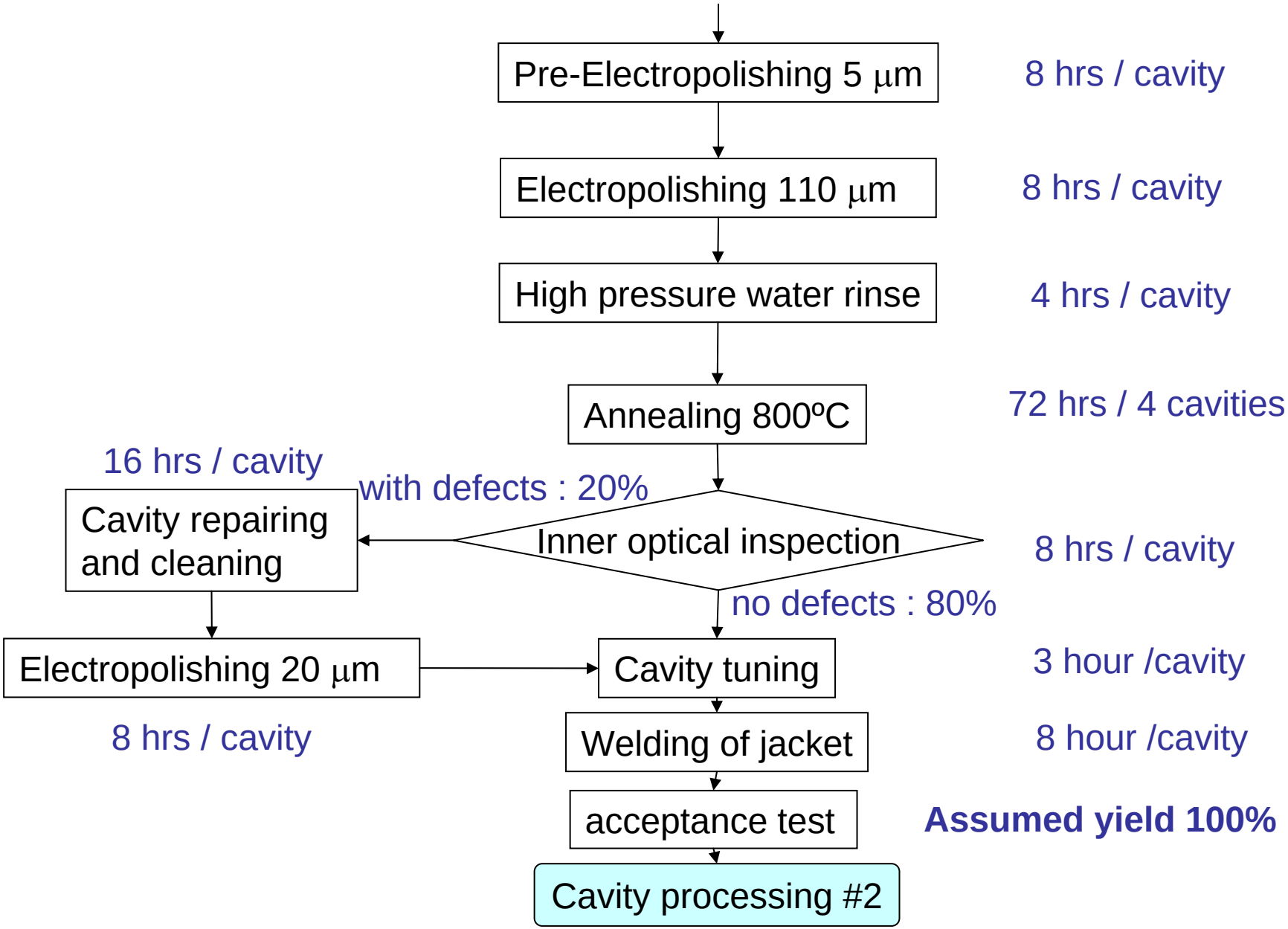
- KEK provided process model and required time
- We proceeded further studies



Cavity fabrication process (2/2)



Cavity processing #1 and dressing



Initial evaluation of number of machines

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- Number of EB welding machines and factory floor space determine cavity production rate.
- Set **# of EB welding machines** to **2**.

Machine and Apparatus			work shift [H/day]	Process			
area	name	#		name	lot	hour[H]	production/year
Cavity fabrication	eddy current crack detection device	1	16	Nb sheet inspection	1	0.25	800
	press machine	1	8	half cell deep drawing	60	2.00	3000
	vertical turning machine	2	16	half cell trimming	1	0.67	600
	3D dimensional measurement	1	8	half cell dimensional measurement	1	0.08	1200
	chemical polishing	1	8	chemical polishing	6	0.50	3200
	electron beam welder	2	16	dumbbell welding	8	6.67	-
	dimensional measurement of dumb-bell	1	16	dumbbell dimensional inspection and repairing	8	4.00	800
	surface inspection of dumb-bell	2	16	dumbbell defect inspection	8	8.00	800
	local grinding machine	1	8	dumbbell defect repairing	1	2.00	800
	electron beam welder	2	16	end group welding	12	15.17	-
				9-cell cavity welding	1	1.75	585
Cavity processing	vertical electro polishing machine	4	16	pre-electropolishing	1	8.00	727
				electropolishing 110mm	1	8.00	-
				electropolishing 20mm	1	8.00	-
	high pressure water rinse	1	16	high pressure water rinsing	1	4.00	800
	anneal furnace	3	24	800ºC annealing	4	72.00	800
	inner surface inspection camera	2	16	inner surface inspection	1	8.00	800
	local grinding machine and ultrasonic rinse	1	16	reparing and cleaning	1	16.00	200
	cavity tuning	1	16	cavity tuning	1	3.00	1067
Cavity dressing	welder	2	16	welding of jacket	1	8.00	800

Example of factory layout

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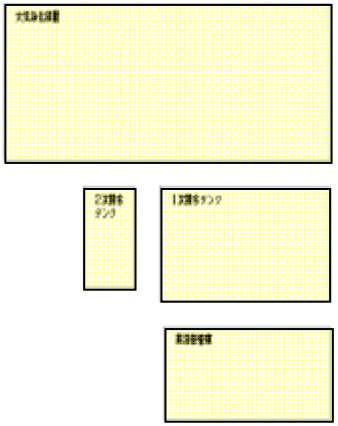
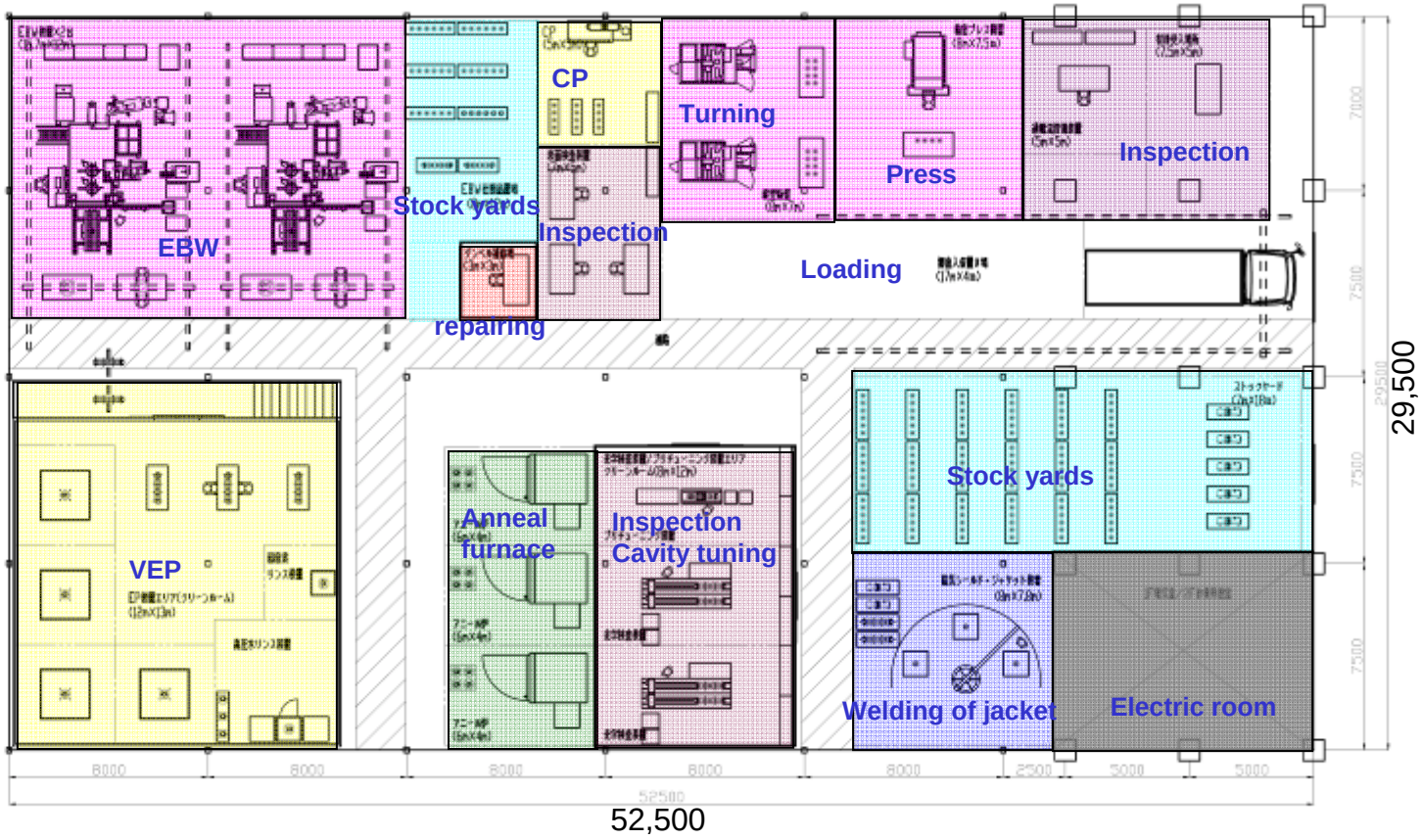
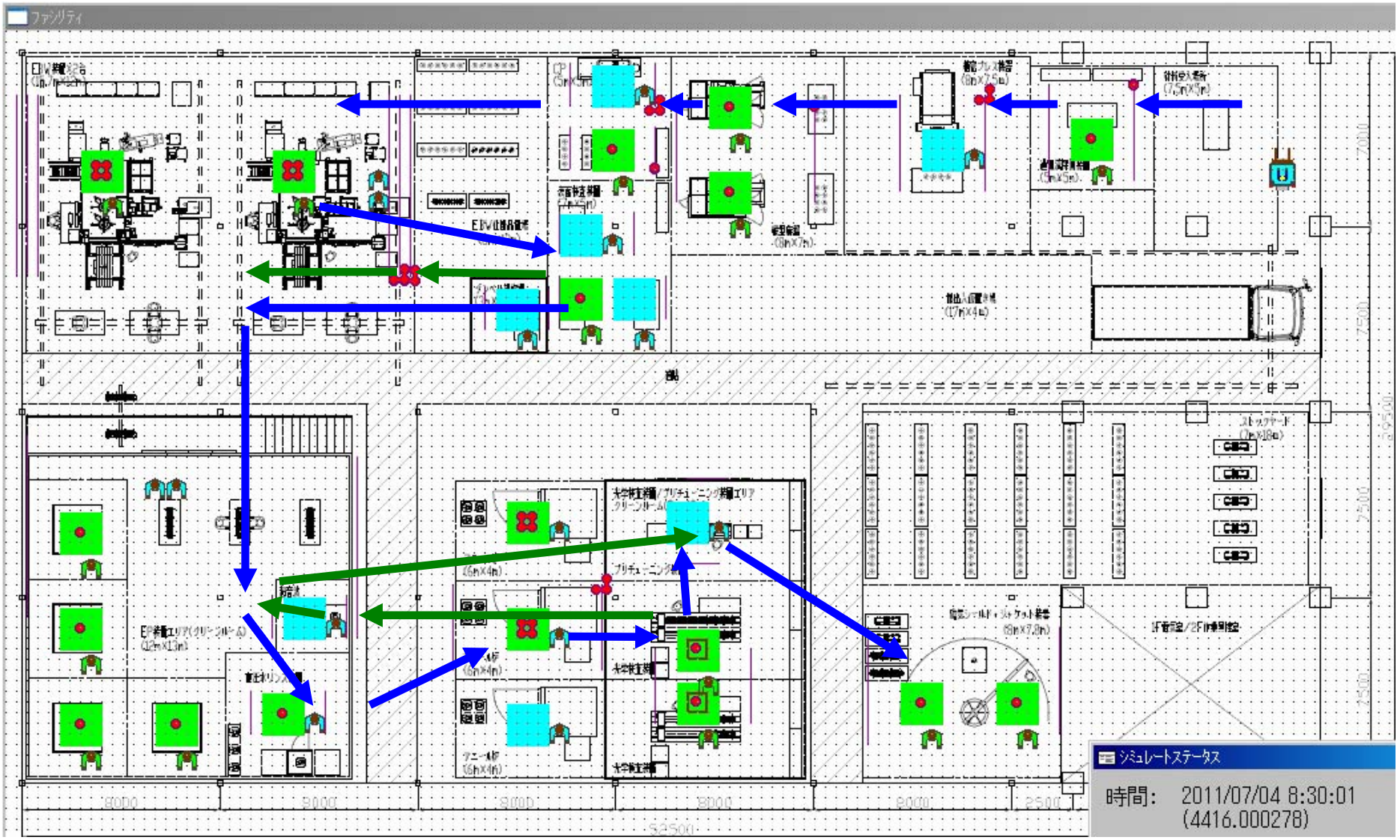
•KEK's R&D facility (52.5mX29.5m)





- VEP/BCP
- Stock yards
- Inspection and tuning
- Welding of jacket
- EB welding / Press / Vertical turning machines
- Anneal furnace
- Dumb-bell local repairing
- Electric room

Simulation of work flow

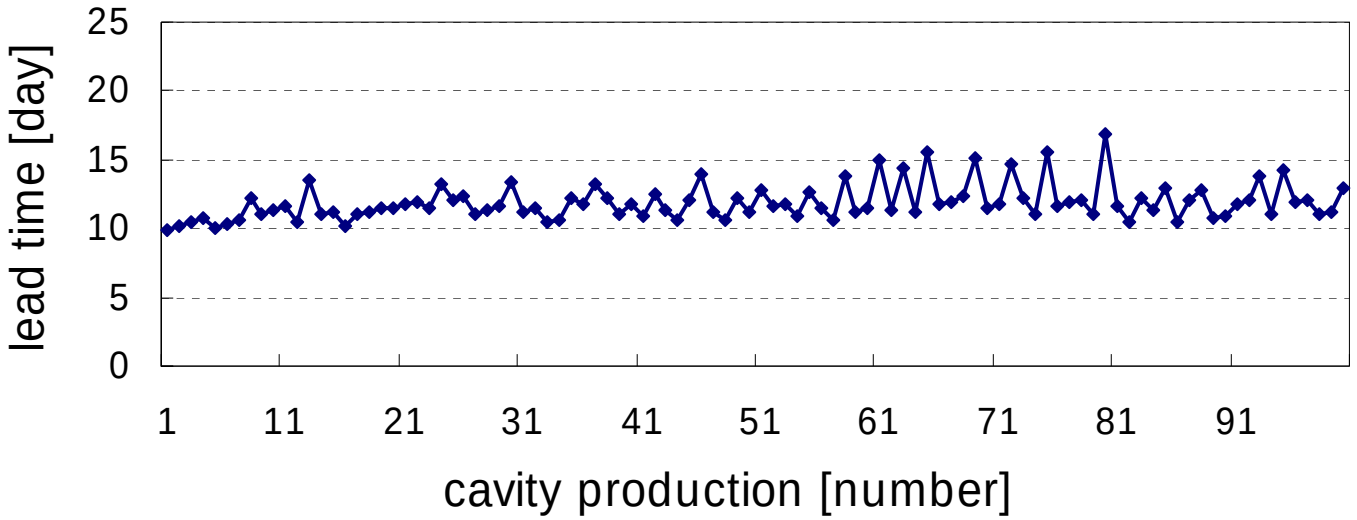


: Work flow : Repair work flow

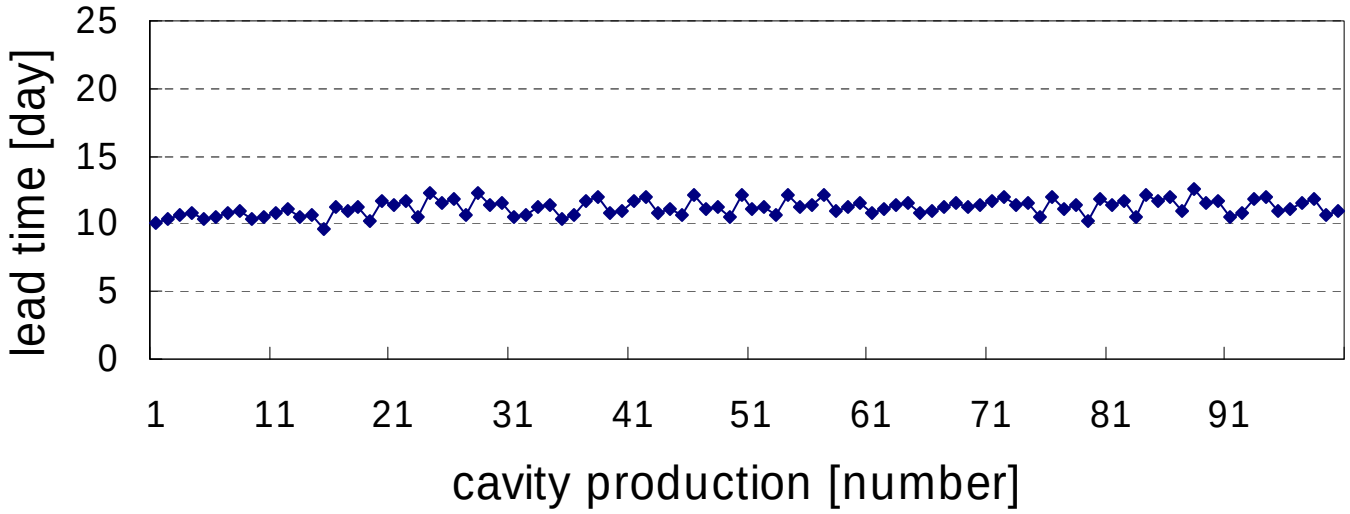
Lead time of cavity production

- Lead time of cavity production : **11.7days** on an average
- Sharp long lead time caused by repairing of dumb-bell and cavity defects

- including defects
- Lead time:11.7day
- Cavity production rate : **540 cavities/year**

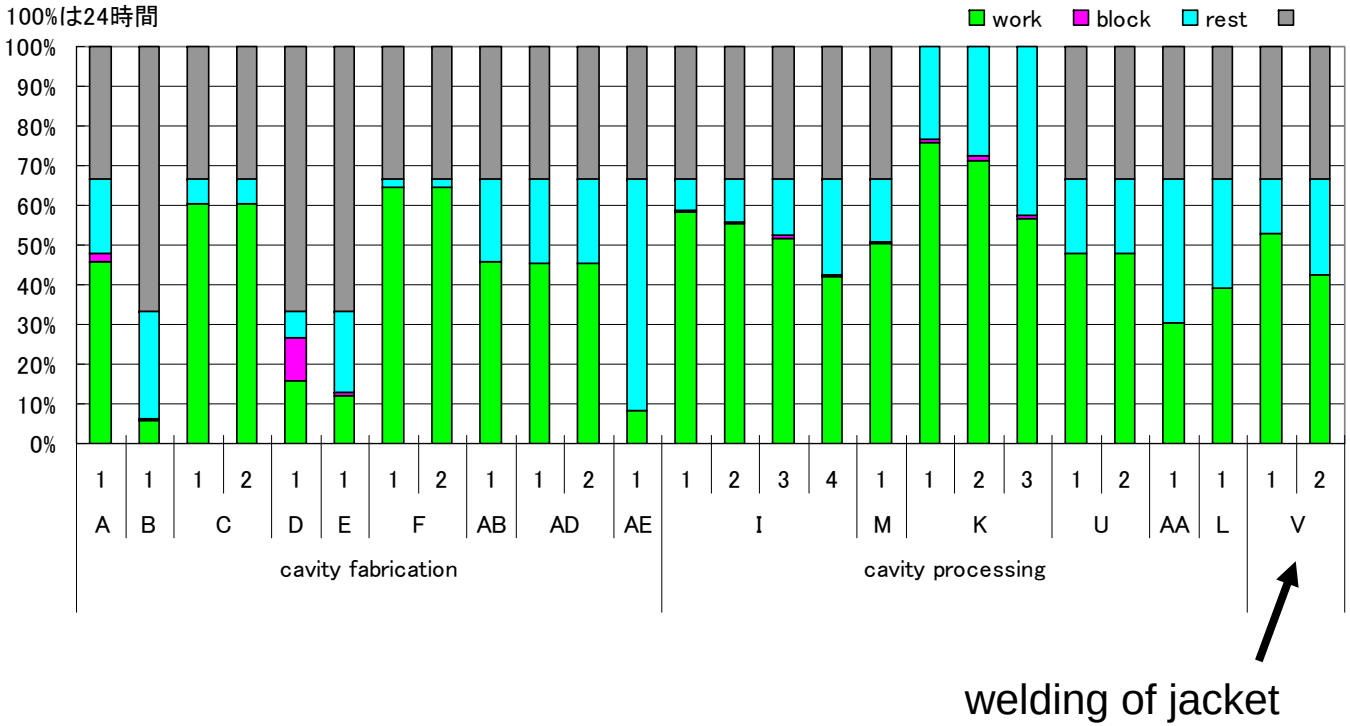


- In case of no defect
- Lead time:11.3day
- Cavity production rate : **550 cavities/year**



Rate of machine operation

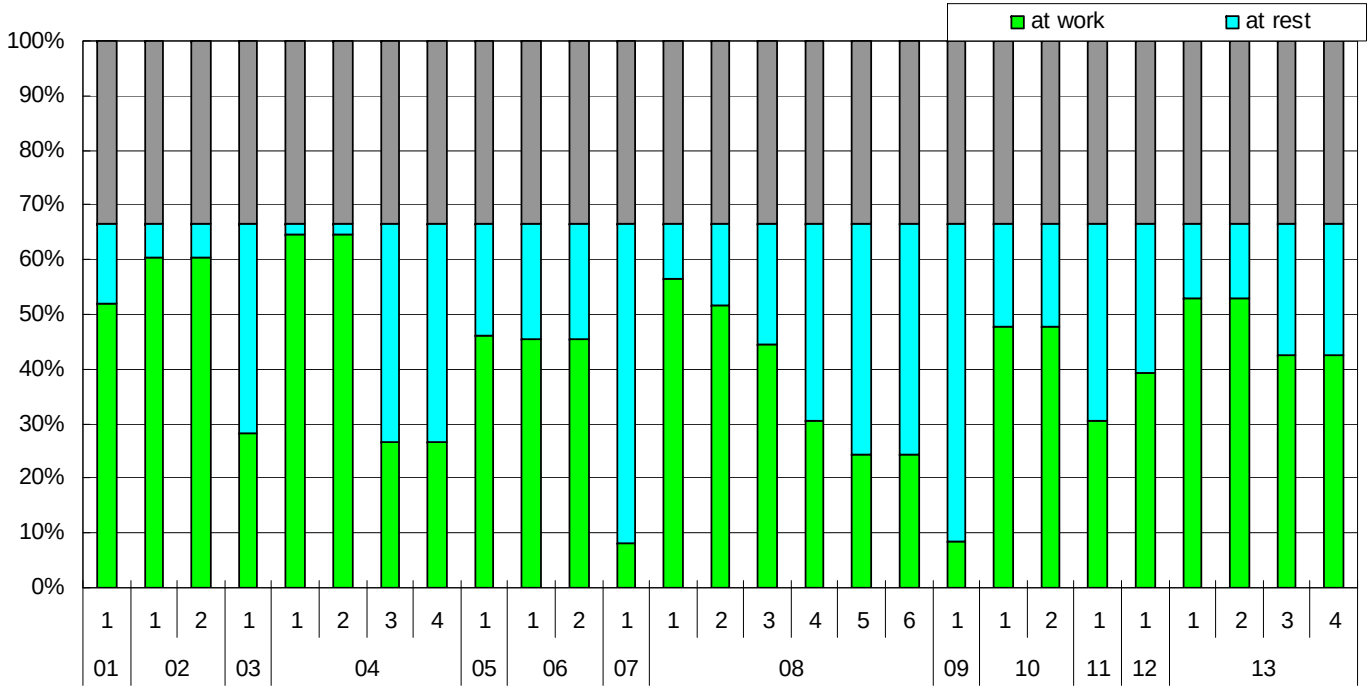
- Two EB welding machine with almost full-capacity operation lead 540 cavities procuction
- Some machines and processes could be reduced to one shift



ID	Machine and Process
A	eddy current crack detection device
B	press machine
C	vertical turning machine
D	Half-cell 3D dimensional measurement
E	chemical polishing
F	electron Beam Welder
AB	dumbbell measurement
AD	dumbbell inner surface defect inspection device
AE	local grinding device
I	vertical electropolishing
M	high pressure water rinse
K	anneal furnace
U	inner surface inspection camera
AA	Reparing ultrasonic cleaning
L	cavity tuning
V	welding of jacket

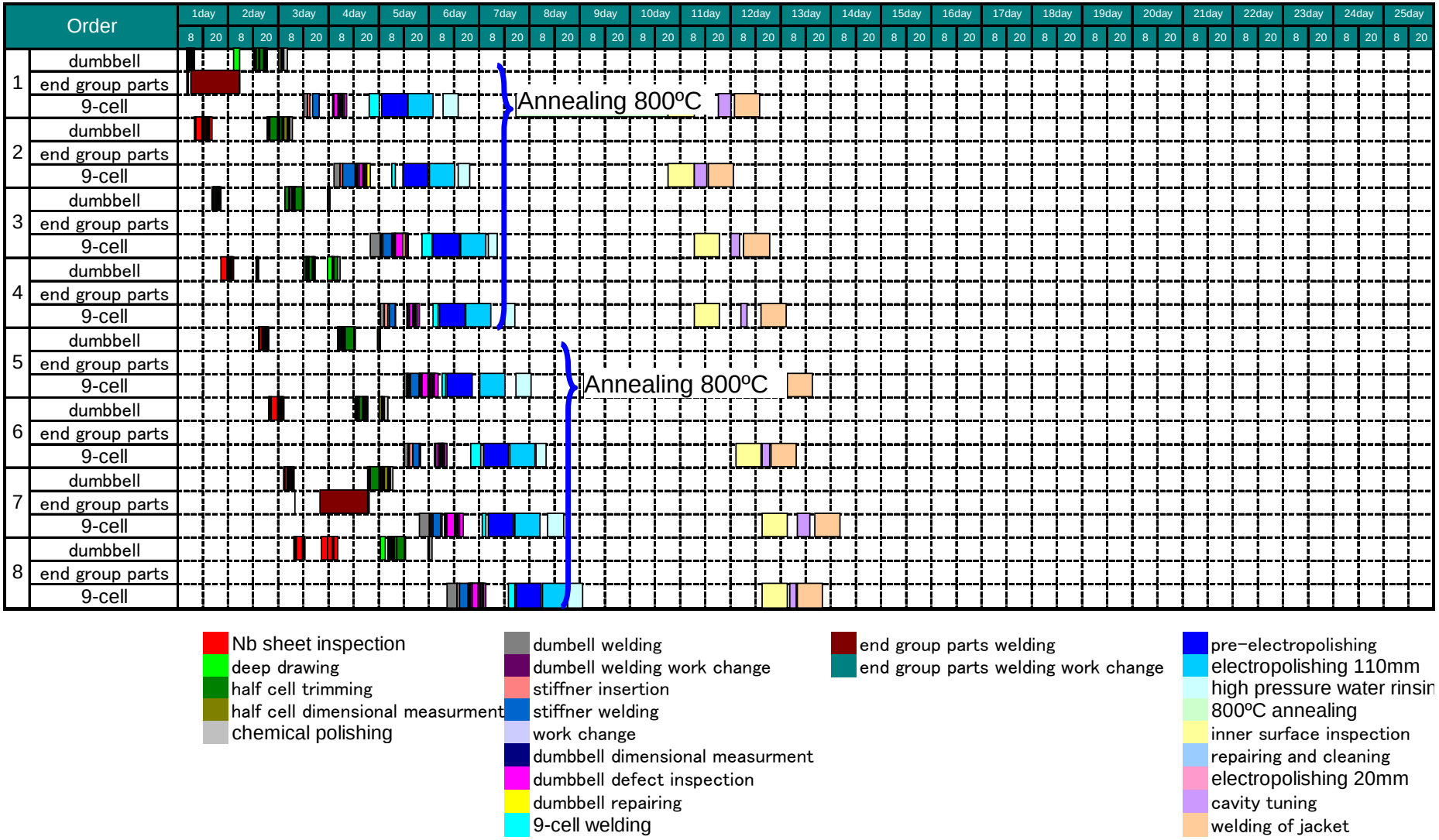
Rate of worker operation

- Workers operate **one or more machines** and/or processes
- EB Welder operator are almost full operation



ID	work and operation
01	eddy current crack detection device
01	press machine
02	vertical turning machine
03	3D dimensional measurement
03	CP
04	EB welding
05	dumb-bell dimension check
06	dumb-bell defect inspection
07	local grinding repair
08	vertical electro polishing
09	high-pressure pure-water rinsing
09	anneal furnace
10	inner optical inspection
11	ultrasonic degreasing
12	cavity tuning
13	welding of jacket

Cavity production Gantt chart



SUMMARY

- Based on each process and time provided by KEK, the required industrial facilities to produce 9-cell cavity have been investigated,
- Dumb-bell process may be a critical pass to determine number of EB welding machines, and **multiple seams per one welding cycle using special jigs** may help to reduce the number of EB welding machines,
- **540 cavities per year** could be manufactured at this ideal factory and **54 workers** are necessary in this simulation study