SERIES PRODUCTION OF BQU AT DESY FOR THE EU-XFEL MODULE ASSEMBLY AT CEA SACLAY

B.v.d. Horst, A. Matheisen, M. Helmig, S. Saegebarth, M. Schalwat,
DESY Hamburg, Germany

Abstract

Each of the 103 XFEL modules foreseen for the EU-XFEL as well as the 3,9 GHZ injector module is equipped with a combination of beam position monitors, superconducting quadrupole and a gate valve connected to the beam position monitor. The subunits are prequalified by the different work package of the EU-XFEL collaboration and handover to the DESY cleanroom. These subunits are assembled in the DESY ISO 4 cleanroom to unit named BQU, quality controlled in respect of cleanliness and handover in status "ready for assembly in ISO 4 cleanroom" for string assembly to the ISO 4 cleanroom located at CEA France. Series production started with production sequences of one unit per week and needed to be accelerated up to five or six units per month (>=1.25 units per week) in beginning of 2015. Analysis of data taken during production and the optimization of work flow for higher production rates are presented.

INTRODUCTION

In 2013 an assembly line for beam position monitors and quadrupole units (BQU) was set up and commissioned at DESY [1]. This production line was designed for completion of one BQU (Fig. 1) per week in the DESY ISO 4 cleanroom at building 28. During continues flow of module assembly these BQU are handed over to CEA by regular transports circulating weekly between CEA Paris and DESY Hamburg.

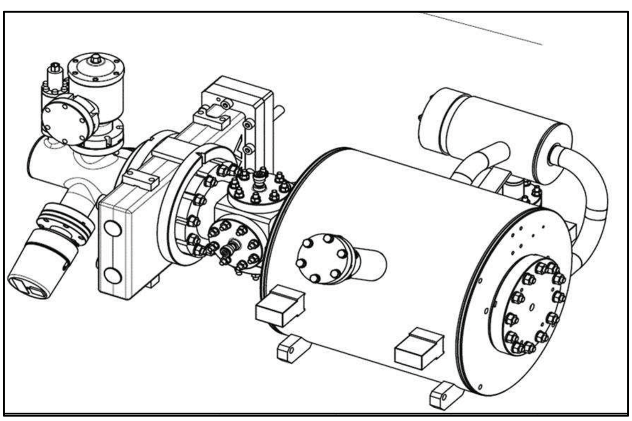

Figure 1: Overview of BQU unit - from left side: vacuum star; gate valve; beam position monitor; s.c. quadrupole; blank off flange.

In autumn 2013 production of modules had to be ramped down due to problems on orbital welds of interconnection between the cavity helium tank service pipes and interconnection bellows of the 2 K helium line [2]. This caused a time delay of several months and had to be compensated by increasing the production rate from 1 to 1.25 or even higher rate of modules per week. Also the BQU production was ramped down and the uprating to 5 BQU per month should be realized without increased man power and avoiding two shifts or week end operations, if possible.

STRATEGY FOR PRODUCTION OF FIVE BQU PER MONTH

The procedures and hard ware for BQU assemblies were analyzed to determine risk and capability for ramp up of production rate. At CEA area a stock of three BQU units had to be ensuring for stable production of modules. During analysis it was found that the existing hard ware, (horizontal assembly device, turn device, wear frame for the HPR system and transport device [1]) can serve for higher production rates than four units per month.

Table 1: Infrastructure Upgrade for BQU Assembly

Workstation	Infrastructure	Units
WS 1	Assembly device	1
WS 2	Turning device + wear frame	1+1
WS 3	Transport tool + vacuum pump	1+1
WS 4	Assembly device + vacuum pump	1+1
WS 5	Transport tool + vacuum pump	1+1
WS 6	Transport box	6+2
WS 7	Transport frame	5+2

Also availability of components and timing for handover of parts for BQU assembly was sufficient for the higher production rate.

Vacuum pumping units and availability of high pressure rinsing stand (HPR) hold the highest risk factor of the analysis.

The number of transport frames and boxes for one BQU per week was not adequate for a stable turn around and the buffer request for module assembly (Table 1).

Each module, when transported from CEA to DESY, is equipped with a vacuum diagnostic system (vacuum star) composed from NW 16 CF angle valve, a venting line with 0.02 µm particle filter integrated and two vacuum gauges (Fig. 2).

This vacuum star is connected to the gate valve and leak checked before handover for BQU assembly. They remain on the units until modules are sent to DESY. After return from module assembly the BQU vacuum stars are

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removed from the modules inside the AMTF module test bench and handed over for re-cleaning before installation to the next BQU. The number of stars is limited to 15 units [4], sufficient for original delivery rates of one unit per week, but cannot serve for the goal of 1.25 units per week.

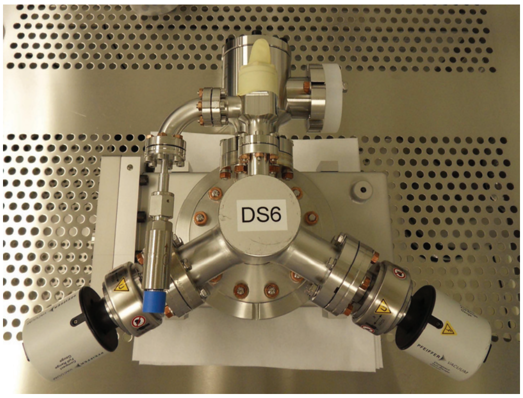

Figure 2: Vacuum diagnostic system (vacuum star).

Only when risk is accepted that there is no back up of vacuum stars and in addition the turnaround time of vacuum stars after modules arrival at DESY can be accelerated, the fifteen units could match to the higher production rate as requested.

Infrastructure Upgrade

By increasing the storage places inside ISO 4 for pre-assembled units, enough buffer of BQU were available to minimize risk of delivery delays due to break down of the HPR system or problems during vacuum checks of BQU.

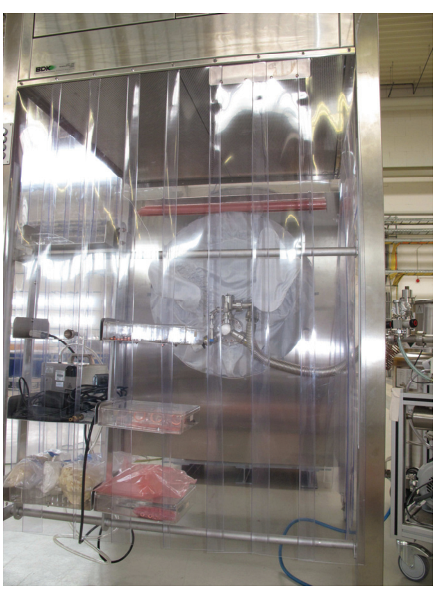

Figure 3: Local cleanroom at AMTF hall for dismounting the vacuum diagnostic stars.

The number of transport frames was increased to a total of seven and the number of transport box units to eight.

For acceleration of the turnaround time of vacuum stars at DESY dismounting from module was shifted from module installation on the test bench to incoming inspection area (Fig. 3). This reduced time delay after arrival and turnaround of vacuum stars became independent from test sequences of modules. A separate local cleanroom of ISO 4 standard was established and work load was taken over by the BQU assembly team.

Table 2: Workstation Load for Work Flow Upgrade to 1.5 BQU per Week

	BQU X	BQU X+1	BQU X+2	BQU X+3	BQU X+4	BQU X+5
1	WS 1 + 2					
2	WS 3	WS 1+2				
3	WS 4	WS 3				
4	WS 5	WS 4				
5	WS 6 +7					
6		WS 5	WS 1+ 2			
7		WS 6 + 7	WS 3			
8			WS 4			
9			WS 5			
10			WS 6+7			
11				WS 1+2		
12				WS 3	WS 1+2	
13				WS 4	WS 3	
14				WS 5	WS 4	
15				WS 6+7		
16					WS 5	WS 1+2
17					WS 6+7	WS 3
18						WS 4
19						WS 5
20						WS 6+7

Increasing the number of vacuum pumps and setting up a backup of HPR was inefficient for this upgrade of delivery rate. It was agreed on using temporarily parts of the infrastructure in use for cavity retreatment. The reduction of 2-3 cavity retreatments per month was acceptable to assure stable production rates of up to 1.5 BQU per week (Table 2).

EXPERIENCE ON SERIES PRODUCTION

BQU Production

During the shortage of module production rate at CEA the BQU assembly continued until the storage area of 10 units in ISO 4 at DESY and the three completed units back up storage at CEA were fielded up (Fig.:4). In January 2015 the infrastructure upgrade and adaption of assembly procedures was completed at DESY. CEA module production ramped up and production became stable beginning of 2015. During continuous flow of production every third week an additional BQU was completed (1.25 BQU/month). For compensation of down time of infrastructures for maintenance or vacation times, frequently every second week an addition BQU was completed (1.5 BQU/month). A rate of five BQU units per month completed in ISO 4 area and handover for string assembly became stable since January 2015 (Fig. 4).

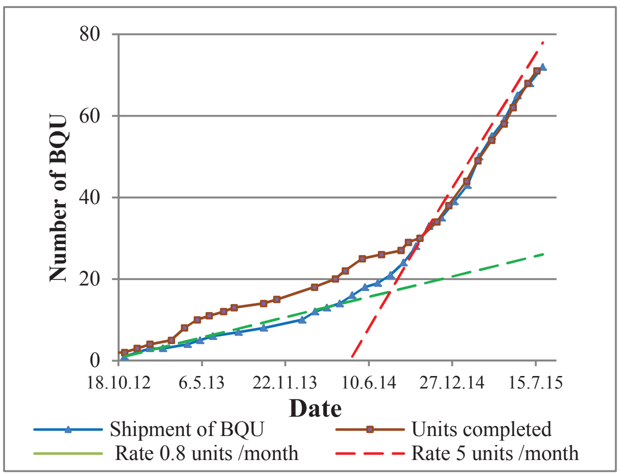

Figure 4: Development over time of assembly rates at DESY and BQU shipments for string assembly at CEA.

Transportation

For quality control of transportation each BQU transport box is equipped with a shock logger (™SENSR GP1) connected to the transport box. It is monitoring the handling of the boxes during loading and unloading and road transport on the truck.

Maximum allowed acceleration should not exceed 3 g. Acceleration gradients below 1.5 g are recorded during transport on truck (Fig. 5).

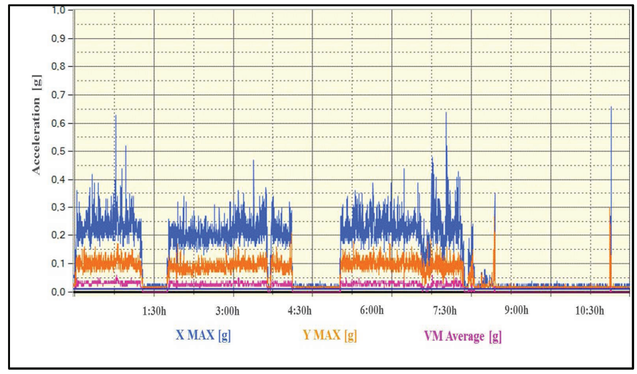

Figure 5: Example of acceleration impact measured during BQU transport by truck from DESY Hamburg, Germany to CEA Paris, France.

On the laboratory areas standard fork lifter, which do not have air cushioning or pneumatic tires are in use for handling of BQU units.

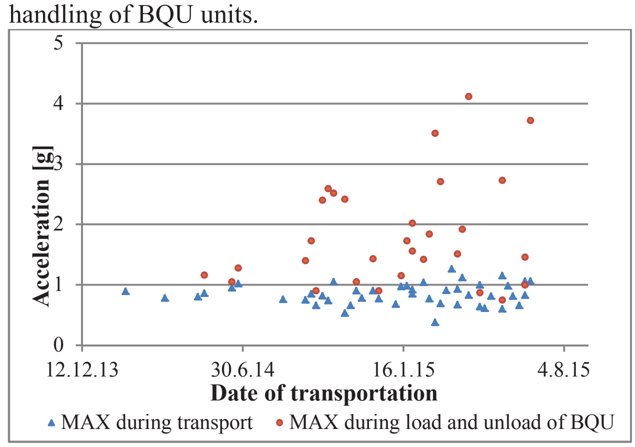

Figure 6: Accelerations measured during transport and handling of BQU.

Before and after truck transport g forces above 2 g (Fig. 6) are recorded. Since production reached 1.25 string assemblies per week three times BQU units were exposed to accelerations well above 3g.

Even with acceleration up to 4.12 g and impact time of several seconds, no influence on quality of BPM or quadrupole performance was found during module acceptance test of module XM 47 where the affected BQU is integrated.

Vacuum Degradation

Before BQU is closed for storage or transport the vacuum is pumped down to < 1*E-8 mbar, a carefully leak check and residual gas analysis (RGA) is done in the DESY ISO 4 cleanroom. No baking of this unit takes place after assembly or HPR.

Before leaving the DESY cleanroom a global leak check is performed (WS 5). The complete BQU, including the vacuum star, is covered by a bag filled up to a level of fifty volume percent of helium. During the ten minutes of exposure to helium the total leak rate has to be below 1E-10 mbar l/sec.

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At CEA the incoming inspection of the BQU includes control of the vacuum by the gauges installed to the vacuum stars. Acceptance level for incoming inspection was set to a total pressure of <= 1E-5 mbar.

During start of string assembly production all BQU failed the incoming inspection at CEA, because total vacuum pressures between 0.01 to 0.1 mbar were recorded (Fig. 7). Intensive leak check did not give any indications for leaks on gaskets or any component. Total pressure could reach the level of <1E-7 mbar in few minutes pump down, when the BQU was connected to a vacuum pumping station [3].

A test series was started to investigate the reduction of total pressure during storage of BQU units.

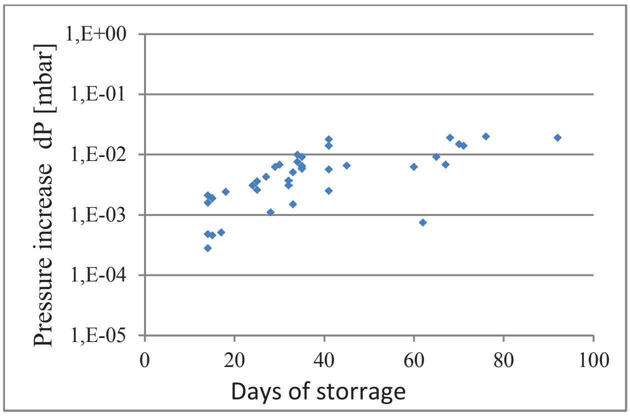

Figure 7: Pressure increase of BQU vacuum without active pumping.

Only one BQU had to be sent back, because a leak was found on one gauge, sealed by rubber gasket [4]. These types of gauges were substituted by brazed once. All others gauges passed the leak check during incoming inspection without indications of leaks after transport [3].

To exclude influence on vacuum by transport and handling, investigations were done on BQU units on stock at DESY cleanroom. It was found that start-up of gauges caused a pressure rise up to 1E-4 mbar, if they were not switched on during pumping down of the complete unit. The handling procedures of vacuum test were adapted to this finding and gauges are switched on at the very beginning of pumping down and turned off right before unit is disconnected from pumping station. After about 40 day of storage, vacuum level reach a stable vacuum value in the 1E-2 mbar range (Fig.8).

Desorption of the about 300 cm2 large surfaces with desorption rate in range of about <1*Exp-10 (mbar l /sec cm2) is identified as origin of degradation of vacuum level. The criteria of incoming inspection at CEA for BQU needed to be corrected. Maximum total pressure measured during incoming inspection at CEA Saclay was removed from the criteria and replaced by a leak check of all flanges and gaskets.

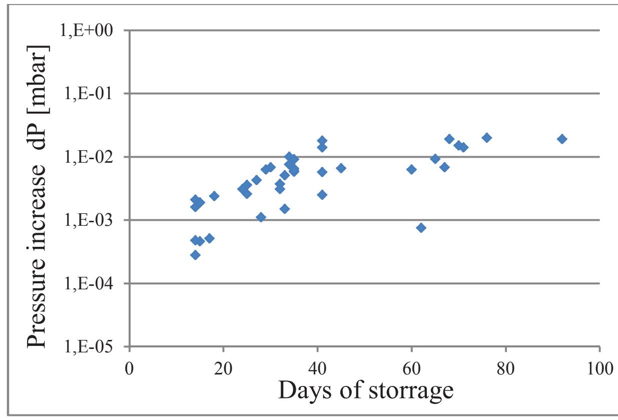

Figure 8: Pressure degradation during storage.

SUMMARY

Since October 2012 seventy five beam position monitor and quadrupole units are completed and handed over for string assembly to CEA Saclay in France. From 2015 on the production rate of modules and BQU was ramped up to an assembly rate of five units per month to keep the final date of XFEL commissioning start. The infrastructure and workflow of BQU completion at DESY was upgraded and can serve now for 1.5 units per week without going for shift or weekend work times. Transports of the BQU are controlled by shock sensors. During transport on truck damping no unit exceeded the maximum allowed value of 3 g. Only during handling with fork lifter or crane g forces up to 4.12 g were observed frequently. For more than twenty days between handout for transport at DESY and incoming inspection at CEA Saclay cleanroom the BQU are not actively pumped. Reduction of total pressure from 10-8 mbar to 10-2 mbar due to desorption of the BQU surface is observed.

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