E13-98-135

ATLAS BARREL HADRON CALORIMETER: GENERAL MANUFACTURING CONCEPTS FOR 300000 ABSORBER PLATES MASS PRODUCTION

1998

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1. INTRODUCTION

Master and spacer plates both are the important elements of the ATLAS hadron barrel calorimeter structure. Their production quality affects strongly on the whole barrel hadron calorimeter assembling quality. Spacer plates geometry (see fig.1) observance allows one to place the scintillators without damaging of their packing materials. The spacer's plate contour is machined with ±0,1 mm precision, and the position precision for the nominal centers of the holes is chosen to be ±0,05 mm. As to the tolerances for holes diameters (∅ 11,4 mm) they were taken to be equal 50 microns.

Master plates geometry (see fig. 2) observance allows one to perform the barrel assembly with the presence of the guaranteed 1,5 mm gaps between two 20 tons heavy MODULES. Master plates side surfaces "create" the side surface of the assembled module. The module length is 5640 mm and the module contains 609 master plates. The maximal module's side nonplanarity will be 0,6 mm (calculated value). About a half of this figure is mainly due to the master plates summed tolerances. This is this sum which affects finally on the module assembly precision. Further increase of the spacer & master plates manufacturing precision is of no sense because of strong rise of production price. (Moreover: even with twofold decreased tolerances we achieve only 20% improvement in the module side surface nonflatness).

Master & spacer plates production technology /1/, /2/, /3/ was discussed many times by the collaboration on its engineering meetings. When discussing the participants took into account 3 major factors: price, time and the expected output. As a result two alternative technologies were determined: the stamping and laser beam material cutting.

For MODULE-"0" absorber plates manufacturing both technologies have been applied: the stamping for the master plates and the laser cutting for the spacers /4/.

After successful MODULE-"0" assembly completion in the Laboratory of Nuclear Problems (April, 1996) /5/ as the immediate task became to be the necessity for choosing of the firms able (in the near future) to perform the mass production of both the master and spacer plates. Here to the above mentioned three factors which affect on the choice of producer the new fourth factor is to be added: the geographic location of the plates producer firm(s). Besides these four economic factors there exists an additional purely technical factor. Not at all any machine building plant is able to perform our order. The very high mechanic precision (severe tolerances) and high output (40800 of master plates and 244800 of spacer plates) demand the high manufacturing culture. The producer is also to have good approach lines (rail/track), big enough storage areas, the adequate manufacturing equipment.

The task to find the producer for master and spacer plates manufacturing happen to be highly nontrivial one.

For the last 2 years period we have established tight connections with many different plants and enterprises in Russia, Belarus, Bulgaria, Slovakia, Czech republic (see fig.3 - photo). There were considered both options of plates production - by laser cutting and by stamping.

As a result with all the factors taken into account the producers for barrel hadron calorimeter absorber plates were determined. As a spacer plates producing firm the Minsk Tractor Plant was chosen with the stamping as a production technology. Master plates production will be done on the TATRA AUTOMOBILE PLANT (Czech republic). The Argonne National Laboratory cutting die will be used when plates stamping.

Russian producers were declined because of a unacceptable high price as well as because there are located to far away of Prague steel producer.

2. SPACER PLATES PRODUCTION EXPERIENCE

The first (test) samples of spacer plates were produced on 4 different factories-candidates for mass-production. Two Bolgarian plants using the HEBAR type laser cutter have both cutted out 10 test units of spacer N 7. Their dimensions control performed with digital caliper "Mitutoyo" has shown -in some cases - the disagreement with the shop drawing. Also the quality of the shearing surface was not satisfactory. Besides that the dimension execution precision was dependent on the laser beam movement direction. It did not allow one to perform the necessary corrections of the cutting control computer programs. Therefore these factories were declined as a potential producers. With another 2 factories the contracts were signed on the stamping dies design & production for only one type of spacers.

For the June-July of 1997 the Minsk Tractor Plant has produced the stamp for spacer # 4 (see fig's 4,5 -photo). First set of spacers were carefully inspected and their dimensions measurements have shown the necessity of some moderate stamp modifications (changes in some of stamp dimensions). After modification completed the another test stamping was undertaken and (after control) quite a satisfactory results have been demonstrated: all the dimensions as well as the tolerances on the spacer elements relative location fully satisfied to the shop drawing demands.

In the December of 1997 the ZTS-plant (Dubnica n/V, Slovakia) prepared the stamp for the spacer # 12 (see fig's 6,7 -photo). The first ready samples dimension measurements have demonstrated the full agreement with the shop drawing spacer geometry (see fig. 8).

As a result it was decided that contract for barrel hadron calorimeter spacers manufacturing will be signed with the Minsk Tractor Plant (MTP). Three essential positive factors were taken into account:

- smaller spacer production price at MTP;
- the production of all 12 spacers types is located in one shop area (in Slovakia same work is to be done on 2 different plants);
- more convenient Minsk plant geographic location.

3. MASTER PLATES PRODUCTION EXPERIENCE

The search for master plates manufacturer was an especially difficult affair. Laser technology for these plates production contains many problems and among them the following essential ones:

- the necessity to have the unique and expensive equipment (for example the TRUMPF laser cutting complex);
- too low cutting speed;
- relatively high price.

The stamping procedure - even if chosen - itself is also not free of some problems:

- the necessity to have a mechanical press with more them 600 tons effort and to have a table of 1 x 2 m^2 dimensions;
- absence of experience of the stamping die construction for 5 mm thick and 1.6 m long details;
- high precision for master plates production;
- high demands to shearing surface quality not easy to achieve.

Minsk Tractor Plant was a possible candidate for the master plates stamping dies designing and constructing. The very main technical problem with MTP was that MTP press although has a desirable effort of 1200 tons, but the supporting table allowed one to produce (to stamp) the plates not longer than 1600 mm. There was a risk to obtain the unsatisfactory plate edges quality when stamping on such a table.

Taking into account the technical, management, time and economy factors the decision was taken to use for the master plates stamping the ready cutting die of the Argonne National Laboratory (USA). The ANL stamp has a horizontal boundary dimensions of 1,1 x 1,905 m^2 .It excludes the use of MTP press and the MTP.

As the master plates steel will be produced in Czech Republic, we have undertaken the new search, more careful one, for the master plates manufacturer both on the Slovakia territory and on the Czech territory. We visited the machine building plants in the cities: Dubnica nad Vagom; Belusa; Medzev; Kosiče; Koprivnice.

Our final choice was the TATRA PLANT in Czech Republic. This plant has about 100 years long experience in machine building industry. They possess 800 tons effort press with a safely large 1,7 x 3,8 m^2 table (see fig. 9 -photo). The railway road approaches to plant and the approach lines are of good convenience. TATRA has also the big enough storage area. This is of a principal significance that TATRA has a well equipped measurement laboratory with 3-coordinate measuring machine; the personal is of a high qualification. Important, that TATRA is only 30 km away of steel producer (Ostrava).

The ANL die was delivered to TATRA in NOVEMBER 1997 and first 12 test samples were punched out (see fig. 10 -photo).

The very main technical features of prototype master plates stamping at TATRA with the use of the ANL die were:

- punching was performed with mechanical press of 800 tons;
- the additional slots were manufactured in the upper part of the moving table of the press to allow one the desirable stamp positioning and to avoid the significant modification of the stamp's design;

- the die top-to-bottom plate relative nonparallelity was 0.2 mm;

- 6 master plates dimensions measurements showed dominating correspondence to the shop drawing demands (see fig's 11-14 and 15 -photo).

The technical possibility of the TATRA plant and its personnel high skill experience allow one the successful performance of the full JINR's order to manufacture 40800 master plates for ATLAS barrel hadron calorimeter.

The decisive management achievement which made possible high precision masters production was the idea to use the Argonne National Laboratory cutting die for plates manufacturing. It gave the significant economy of material & financial resources as well as lead to the noticeable reducing of the preparation stages to start plates mass production.

4. CONCLUSION

Master and spacer plates manufacturing must guarantee the high precision contour. Besides that their thickness are to be within ±30 microns tolerance. Ordinary rolled steel sheets have noticeably worse thickness spread. Therefore for absorber plates production we ordered a special rolled steel. All the above indicated circumstances make the plates production quite an expensive and serious procedure; only 1-2 % level of defects is allowed. For fast detection of nonsatisfactory plates appearance in production process as well as for "transparent and controlled" relations between ordering organization and plates producers when ready plates accepting the JINR developed quality control programs and necessary technical specifications for mass production of master and spacer plates of ATLAS TILECAL (see Appendix). The QC program says: "The main goal of the QC Program is to secure the permanent control of the master and spacer plates fabrication and to meet the drawing requirements".

When signing contracts between JINR and MTP on spacers production by Minsk Tractor Plant and between JINR and ZTS on master plates production in TATRA our QC program entered to contracts as their integer part.

5. FIGURE CAPTURES and PHOTO DESCRIPTIONS:

Fig. 1. Spacer plates.

Fig. 2. Master plate.

Fig. 3.-(photo)-Good for our purposes 800 t press UDO-800 on the possible plant for mass production of master plates (Medzev, Slovakia). Denied as the press working table dimensions were slightly smaller than stamp site (September' 97).

Fig. 4.-(photo)-Cutting die for spacer # 4 inserted into the press (Minsk, July' 97).

Fig. 5.-(photo)-Two ready spacers # 4.

Fig's 6,7.-(photo)-Cutting die for spacer # 12 inserted into 500 t press (Belusa, Slovakia, December' 97).

Fig. 8. Distribution deviation measured data from nominal dimension for spacer #12.

Fig.9.-(photo)-The TATRA Plant (Czech republik). 800 t press LUD-800 we have chosen for master plates mass production (September '97).

Fig.10.-(photo)-The TATRA Plant: punching of master plates in progress (November, 5, '97).

Fig's (11-14) give the results of the measurements of the master plates essential dimensions, which are to be kept within the shop drawings tolerances as these dimensions affect strongly on the final barrel assembly quality:

Fig. 11. Key way "measured - nominal" widths distribution for the master plate narrow part.

Fig. 12. Key way "measured - nominal" widths distribution for the master plate wide part.

Fig. 13. The deviations of the measured (A) hole center positions from the nominal ones.

Fig. 14. The deviations of the measured (B) hole center positions from the nominal ones.

Fig. 15-(photo)-Part of ATLAS TILE-CAL team with master plate after punching: results of master plates measurements are good (TATRA Plant, November, 5, '97).

Fig's (3-7,9)-(photo)- made by N.Topilin
Fig's (10,15)-(photo)- made by L.Adamčik

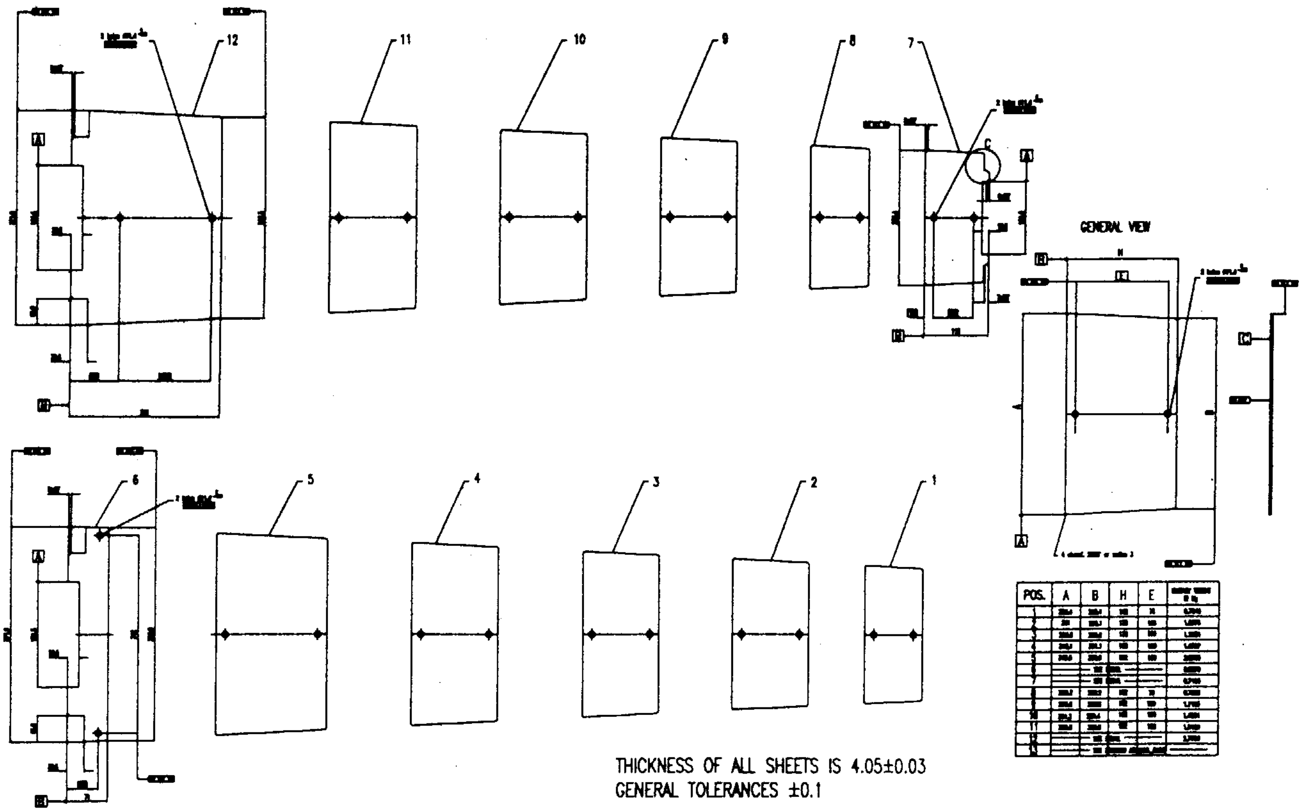


Fig. 1. Spacer plates.

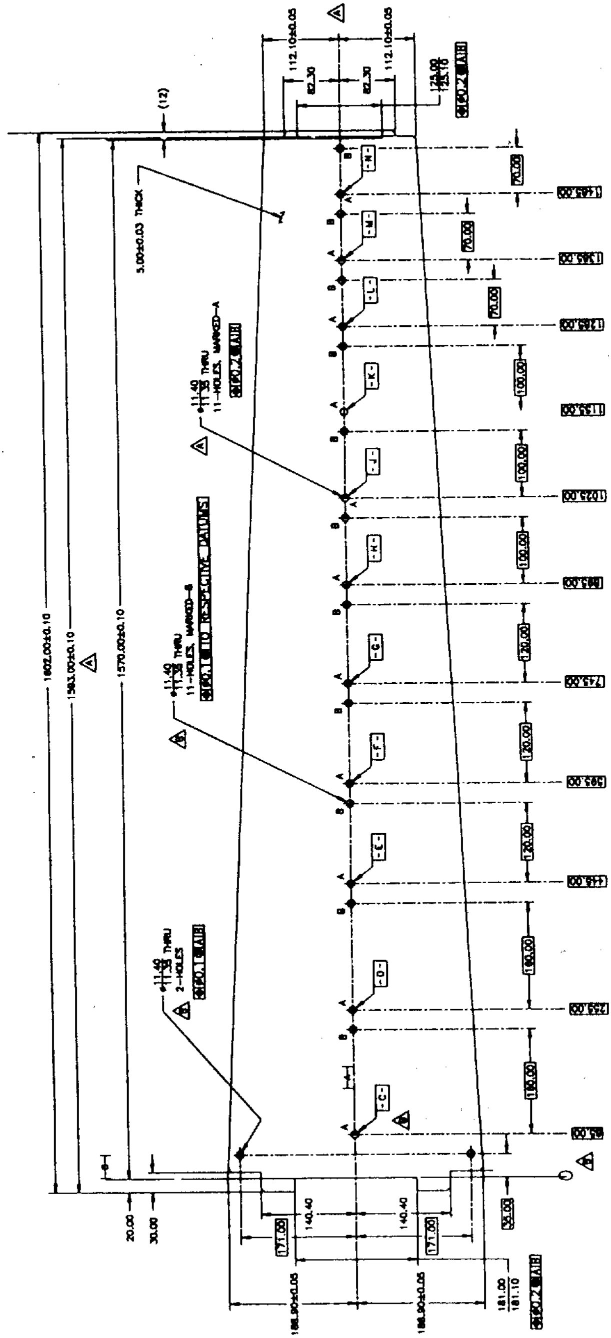
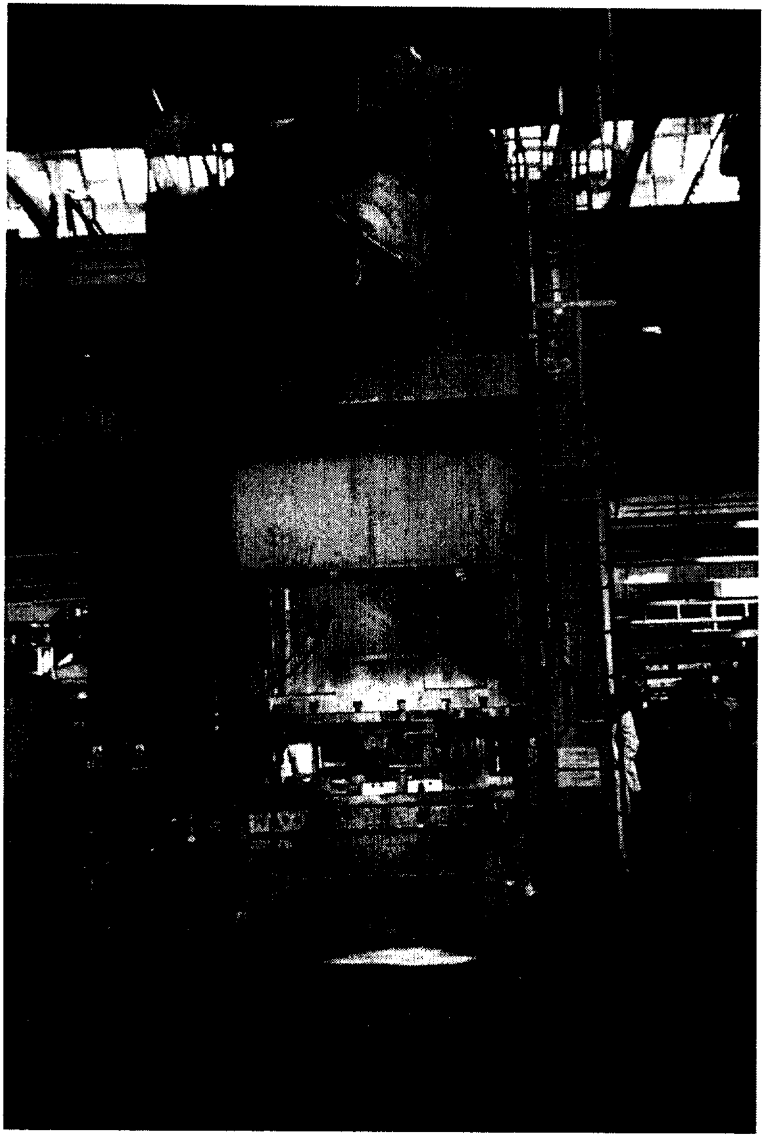


Fig. 2. Master plate.



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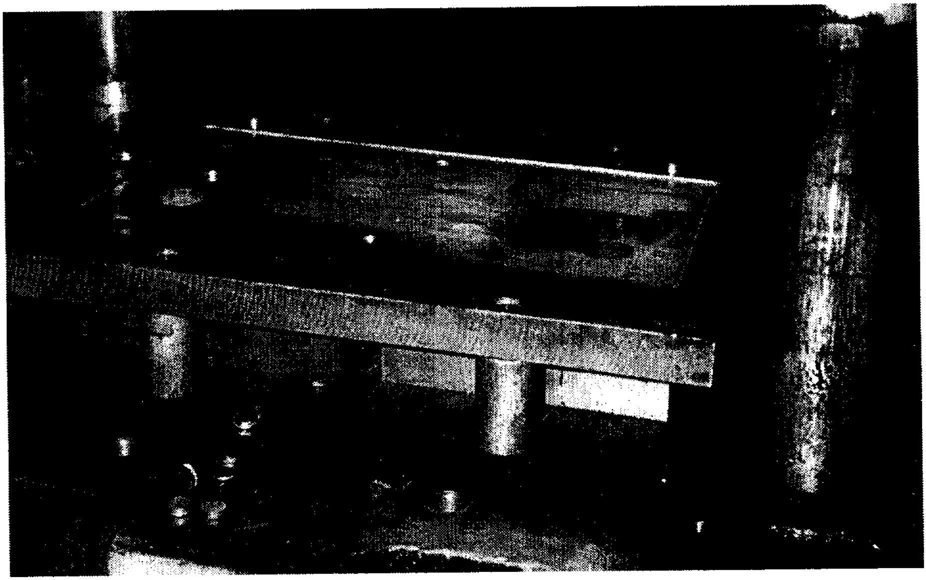


Fig. 4.-(photo)-Cutting die for spacer # 4 inserted into the press (Minsk, July' 97).

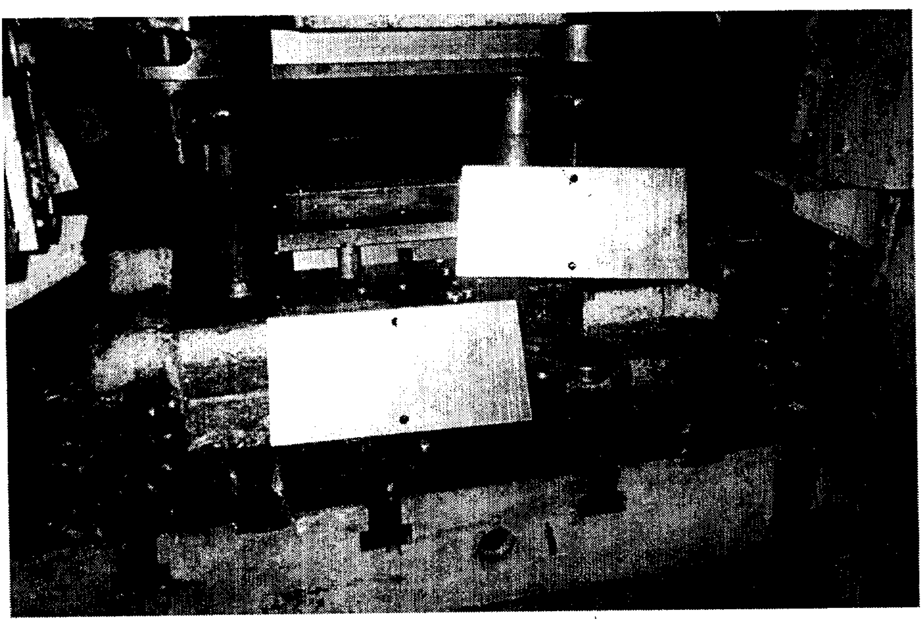
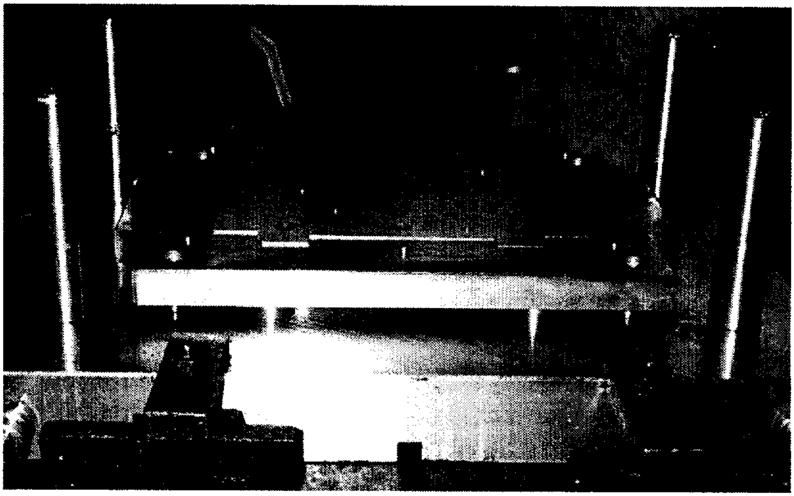
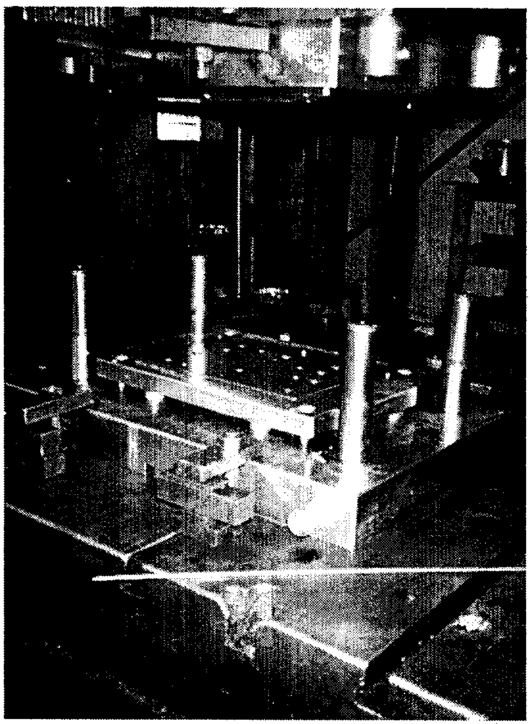


Fig. 5.-(photo)-Two ready spacers # 4.





Fig's 6,7.-(photo)-Cutting die for spacer # 12 inserted into 500 t press (Belusa, Slovakia, December' 97).

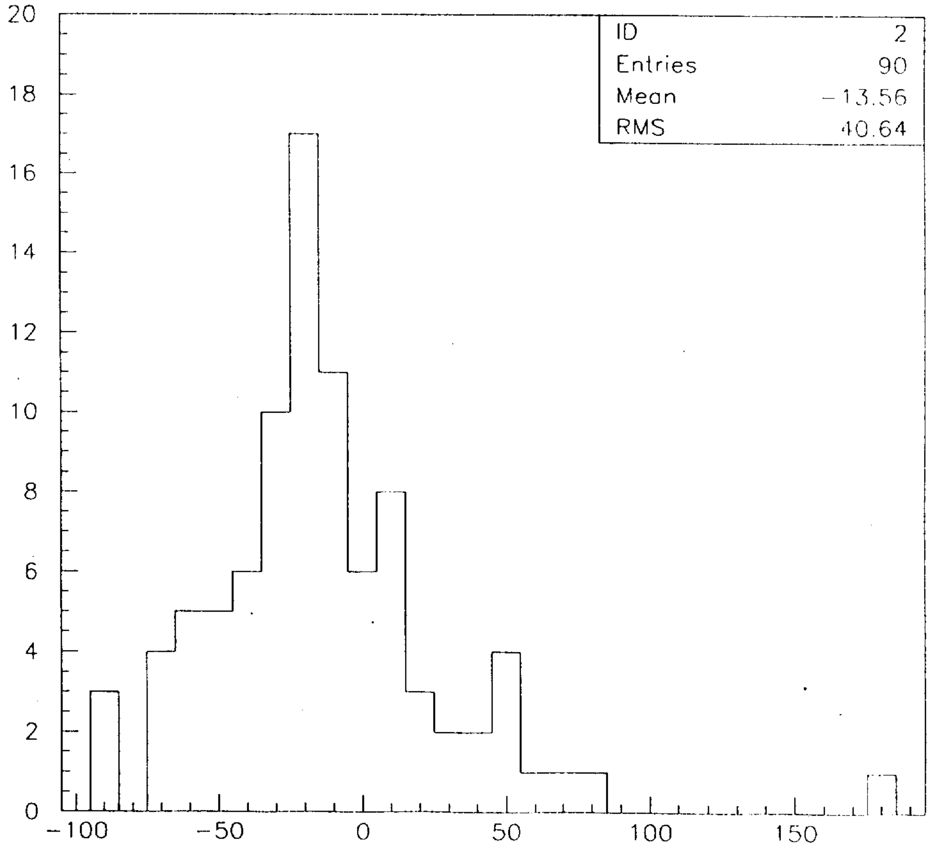


Fig. 8. Distribution deviation measured data from nominal dimension for spacer #12.

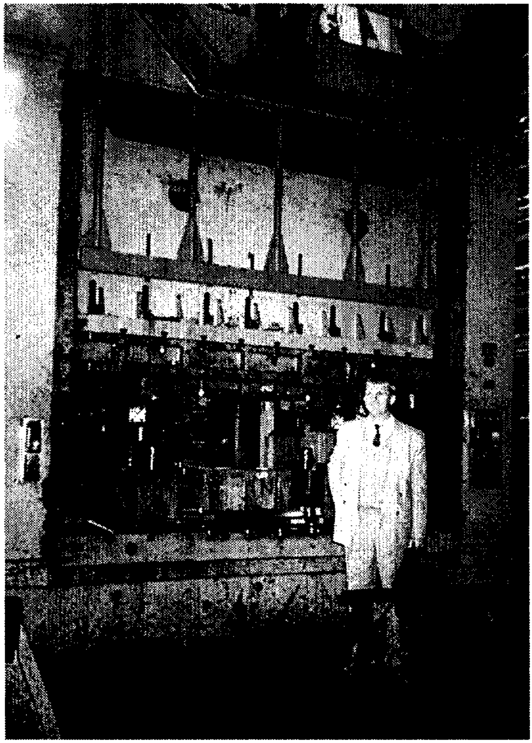


Fig.9.-(photo)-The TATRA Plant (Czech republik). 800 t press LUD-800 we have chosen for master plates mass production (September '97).

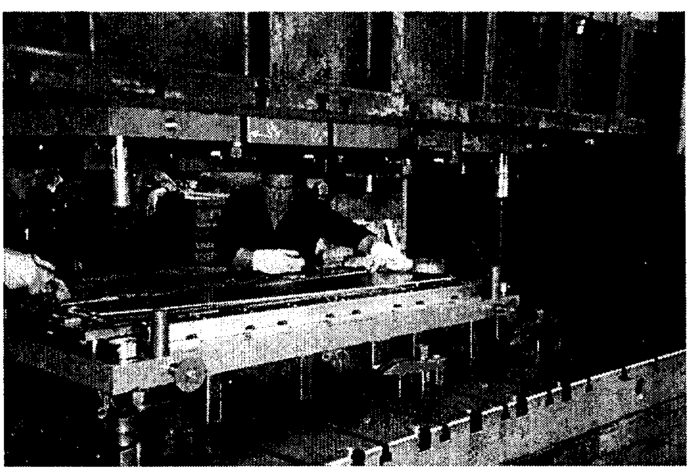


Fig.10.-(photo)-The TATRA Plant: punching of master plates in progress (November, 5, '97).

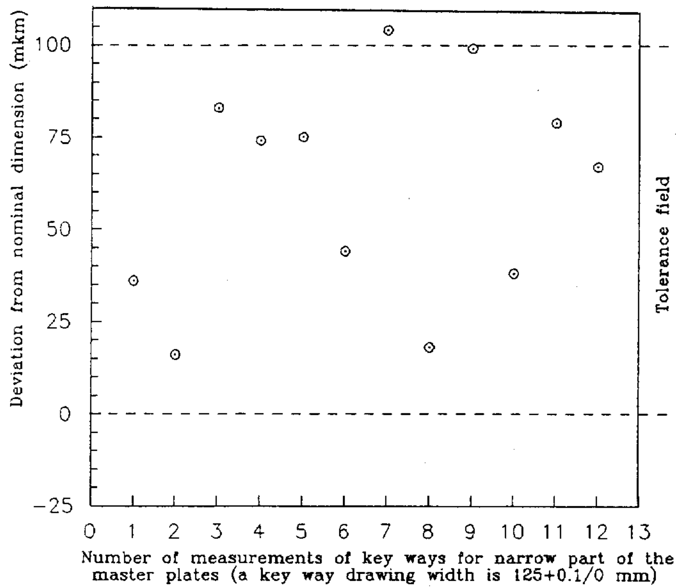


Fig. 11. Key way "measured - nominal" widths distribution for the master plate narrow part.

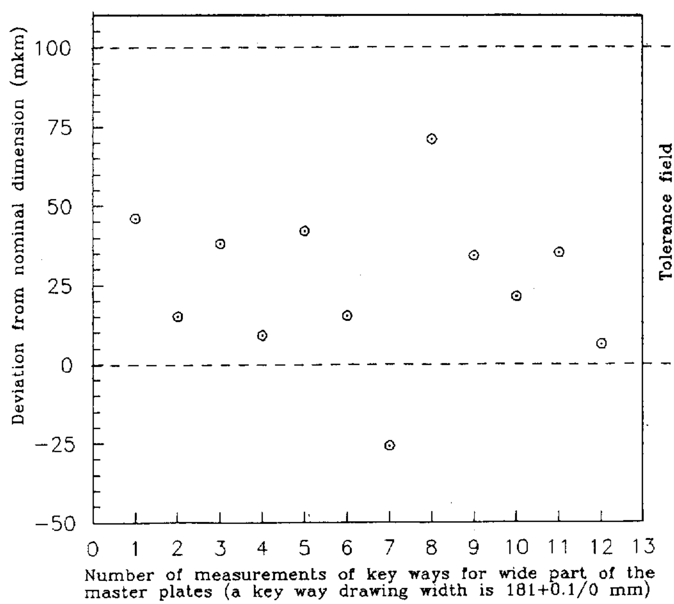


Fig. 12. Key way "measured - nominal" widths distribution for the master plate wide part.

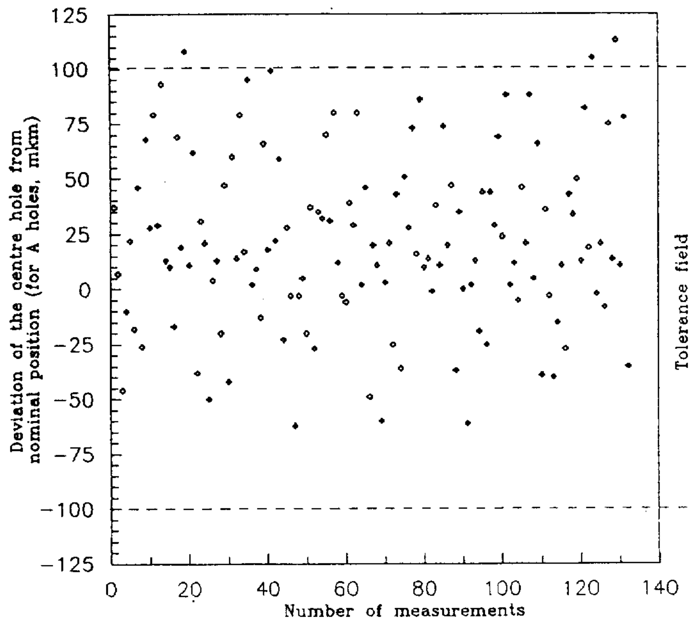


Fig. 13. The deviations of the measured (A) hole center positions from the nominal ones.

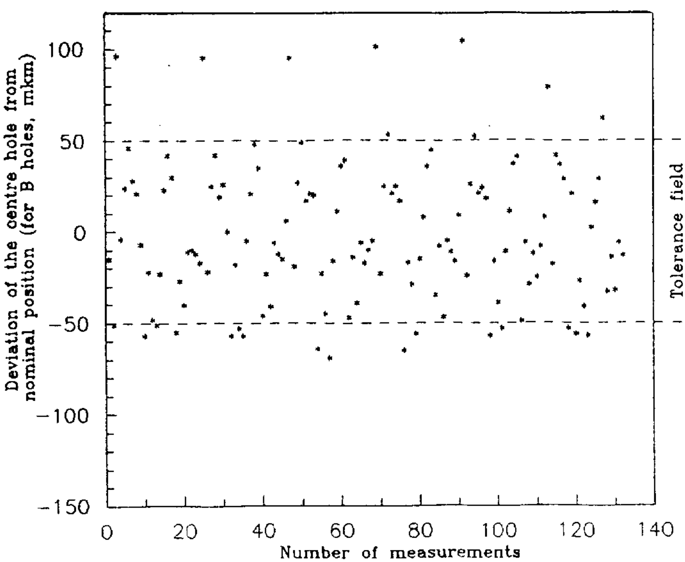


Fig. 14. The deviations of the measured (B) hole center positions from the nominal ones.

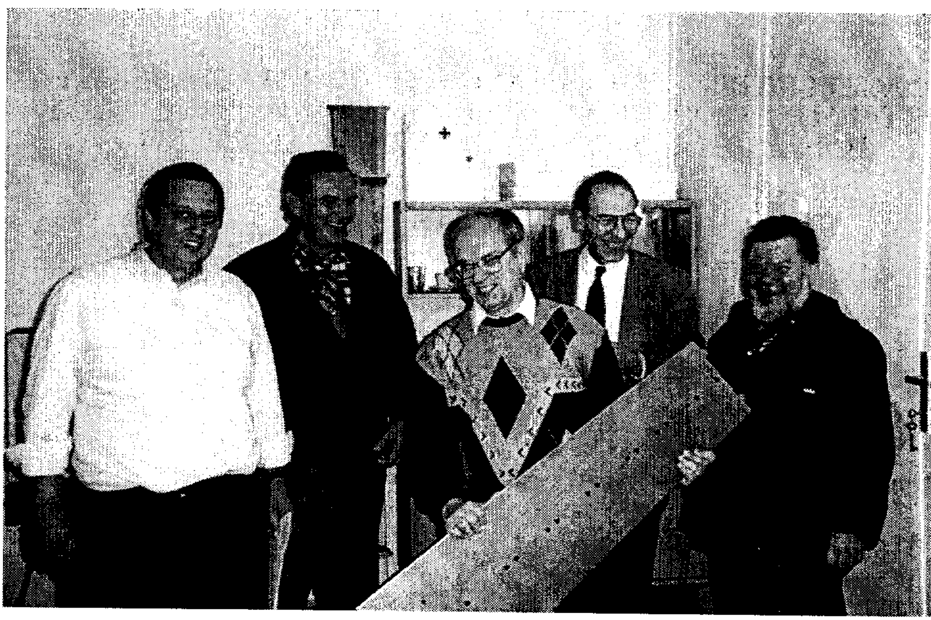


Fig. 15-(photo)-Part of ATLAS TILE-CAL team with master plate after punching: results of master plates measurements are good (TATRA Plant, November, 5, '97).

6. APPENDIX

JOINT INSTITUTE FOR NUCLEAR RESEARCH
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ATLAS TILECAL
30 November 1997

QUALITY CONTROL PROGRAM AND TECHNICAL SPECIFICATIONS FOR THE MASS PRODUCTION OF THE MASTER AND SPACER PLATES FOR THE ATLAS BARREL HADRON TILE CALORIMETER

Atlas Tilecal collaboration

Item	:	Master and Spacer plates cutting for the barrel
PBS #	:	5.1.2.1 and 5.1.2.2
Quantity	:	40800 masters , 20400 spacers sets
Date of tendering	:	15 December 1997
Date of delivery	:	30 July 1998 masters , 15 October 1998 spacers
To be delivered to	:	Prague, Pisa, IHEP, and JINR
Institutes involved	:	JINR, CERN
Document responsible	:	*Yu. Lomakin, M.Nessi, N.Topilin*
Document due the	:	*1st December 1997*

1. Introduction

The Quality Control Program (QC Program) defines the set of the requirements used by the Joint Institute for Nuclear Research (quoted as Atlas representatives in this paper) at the interaction with the master and spacer plates production plants.

QC Program is the inalienable part (the Annex I) of the Contract Kxxxx/97 between JINR and ATLAS (and the master and spacer plates producers).

The main goal of the QC Program is to secure the permanent control of the master and spacer plates fabrication and to meet the drawing requirements. The application of this QC Program begins from the receipt by the producers of the steel sheets to fabricate the master and spacer plates and ends after the shipping of the ready ware to the customer (users).

Part I. The mass production of the master plates.

The incoming control of the steel sheets.

Before placing the sheets on the press the producer:

checks:

- the supplier's name
- the type of the material delivered
- the amount of sheets within the package

performs a visual inspection of the sheet packing to be convinced of the absence of mechanical damages. In case of damage on part of the shipment, this part should be put a part, the damage communicated to the transport company the supplier of the steel and Atlas.

The Die inspection.

Mounting and usage of the ANL die.

The producer is responsible for the correct mounting of the die. The parallelism of the die will be measured after mounting on the press and a report will be handled to the customer representative before any punching will be done.

Before starting the mass production the producer fabricates 6 plates which will be measured using 3d measuring machine in the presence of the customer representative. If the measurement results are positive then mass production can start.

The producer is responsible for the timely cleaning of the die from all accessory objects or material present on the die or on the sheets before any plate is stamped. This is very important in order to avoid permanent damages on the die itself.

Punching QC.

Master plates punching.

The geometry control of the master plates is done in 3 steps:

1) The visual inspection of the plates just during removal from the press.

2) Using a dedicated template (gauge plate) provided by Atlas on all punched masters. Masters not passing this test will be put on the side and later handled to ATLAS. The goal of the control is to detect large mechanical defects. The control is done just after removing the plates from the press. The defective plates are stored separately. If the defective plates are more then 1% of the day production, punching is stopped. The producer informs the customer (ATLAS) about it.

3) Performing detailed measurements using a 3-D machine. One per each working day or one every 600 plates. ATLAS will be prompted informed if any deviation from the standard quality occurs. The protocol of these measurements will be discussed in advance with the ATLAS representatives. The measured plates should be marked, numbered and the steel batch recorded.

In general the master plates that are defective should be marked, numbered and the steel batch recorded.

Deburrring process.

For the first 30600 punched master plates, both surface sides have to be deburred on a dedicated time saver machine. This operation is necessary for 2 reasons:

- To prepare the master plate surfaces for the next gluing operations
- To remove all flashes (burrs).

The deburring quality is defined by comparison with samples provided by Atlas.
Before deburring the master plates, most of the oil must be removed (for example using paper)
Atlas will provide to the firm the time saver machine and all abrasive belts spare parts.
Periodically (to be defined with Atlas) the Ra (roughness parameter) should be measured and compared with the Atlas sample in order to determine if the tools (for example belt) should be changed. The plates measured should be marked, numbered and the steel batch recorded.

Surface protection.

Just after the deburring process is finished, a film of oil of the type DAMINOL must cover all master plates. ATLAS provides this oil in the requested quantity. This operation should ensure rust protection during transportation and storage, before the next assembly operation. The same surface protection should be done on the rest of the plates, which will not go through the deburring phase.

Packing.

All plates passing the QC process after the surface protection will be put on a pallet. 60 masters will be put on a single pallet. The same pallets used to carry the incoming steel sheets can be used.
Each master plate set is then covered using a special film-paper of the type STAKOR and is fastened by steel belts in order to fix the set on the pallet. Each pallet should indicate from outside the number of master plates, the date of the punching and the reference to the incoming steel sheets material.

Transportation.

The transport of the master plates to the next assembly plants is carried out by cars or by railway. Loading of the pallets to the transport platform is fulfilled in one layer. The master plates which didn't pass the deburring process or which have been declared bad during the QC must be delivered to JINR Dubna. The rest of the plates is shipped to 3 addresses in equal parts: Pisa (10200 masters), Prague (10200 masters) and Protvino (10200 masters).

Part II. The mass production of the spacer plates.

The incoming control of the steel sheets.

Before placing the sheets on the press the producer:

checks:

- The supplier's name
- The type of the material delivered
- The amount of sheets within the package

Performs a visual inspection of the sheet packing to be convinced of the absence of mechanical damages. In case of damage on part of the shipment, this part should be put a part, the damage communicated to the transport company the supplier of the steel and Atlas.

The Dies qualification.

The producer is responsible for the right fabrication and usage of the dies for the spacer plate production. These dies have to allow the punching of the spacer plates in accordance to the cutting scheme.
ATLAS and the producer before beginning of the dies manufacturing must agree the cutting scheme for the spacer production. All different cutting layouts should be tested.
Before the beginning of the spacer plates mass production the producer fabricates 6 spacer plates of each type in the presence of the customer representative. The customer does the control measurements of the punched plates. If the results of the measurements are positive the producer can start mass production with the ATLAS agreement.
In case the result of the measurement is not satisfactory the producer must correct the die. After the correction the qualification steps restart from the beginning. The same procedure is valid any time a die has to be reshaped.

The producer is responsible for the timely cleaning of the dies from all accessory objects or material present on the die or on the sheets before any plate is stamped. This is very important in order avoid permanent damages on the die itself.

Punching QC.

Spacer plates punching.

The geometry control of the spacer plates is done in 2 steps:

1) The visual inspections of the plates just during removal from the press or prior oiling and packing. The defective plates are stored separately. If the amount of bad plates represent more than 1% of the daily production, punching is stopped. The producer informs the customer (ATLAS) about it. The production can be continued only by the

agreement of the ATLAS representative after the reason of the problem has been found and solved.

2) Performing detailed measurements using a 3-D scanner or a digital caliper. Six plates every 4000 punched plates will be measured in detail, according to a given protocol. The protocol of these measurements will be discussed in advance with Atlas.
Each set of measurement will be transmitted to the Atlas representative. In case of problems production will be stopped and the problem will be solved prior any restarting of the mass production in accordance with the Atlas representative. The measured plates should be marked, numbered and the steel batch recorded.

In general the spacer plates that are defective should be marked, numbered and the steel batch recorded.

Deburrring process.

For the first 15300 punched spacer sets, both surface sides of each spacer have to be deburred on a dedicated time saver machine. This operation is necessary for 2 reasons:

- to prepare the master plate surfaces for the next gluing operations
- To remove all flashes (burrs).

The deburring quality is defined by comparison with samples provided by Atlas.
Before deburring most of the oil must be removed (for example using paper).
Periodically (to be defined with Atlas) the Ra (roughness parameter) should be measured and compared with the Atlas sample in order to determine if the tools (for example belt) should be changed. The plates measured should be marked, numbered and the steel batch recorded.

Surface protection.

Just after the deburring process is finished, a film of oil of the type DAMINOL must cover all plates. Atlas provides this oil in the requested quantity. This operation should ensure rust protection during transportation and storage, before the next assembly operation. The same surface protection should be done on the rest of the plates, which will not go through the deburring phase.

Packing.

All plates passing the QC process after the surface protection will be put into a wooden box. 66 full sets of spacers will find place on a single box. All spacers will be packed inside a unique film of polyethylene inside the box. Fixations will be organized to avoid movements of spacers

inside the box during the transport. A proposal in this sense should be made to Atlas before starting the production.
Each box should indicate from outside the number of spacer plates, the date of the punching and the reference to the incoming steel sheet material.

Transportation.

The transport of the boxes containing the plates to the next assembly plants is carried out by cars or by railway. Loading of the pallets to the transport platform is fulfilled in one layer. All plates which didn't pass the deburring process or which have been declared bad during the QC must be delivered to JINR Dubna. The rest of the plates is shipped to 3 addresses in equal parts: Pisa (5100 sets of spacers), Prague (5100 sets of spacers) and Protvino (5100 sets of spacers).

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15.	Experimental physics of nuclear reactions at low energies
16.	Health physics. Shieldings
17.	Theory of condensed matter
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Аликов Б.А. и др. E13-98-135

Адронный баррель-калориметр установки АТЛАС:

основные концепции подготовки производства 300000 абсорберных пластин

Данная работа подводит итог почти 4-летнего периода исследовательско-технологических работ по определению приемлемого во всех отношениях (цены, времени, места) варианта изготовления около 300000 абсорберных пластин барреля адронного калориметра установки АТЛАС. Высокая точность (± 100 микрон) изготовления этих пластин (главных строительных элементов адронного калориметра), большие геометрические размеры (от 0,2 м до 1,6 м) сделали эту задачу нетривиальной. Потребовался длительный диалог с промышленными предприятиями России и ближнего зарубежья, были опробованы различные технологии на ряде предприятий, прежде чем было принято окончательное решение.

Приложением является программа контроля качества и технические спецификации для массового производства мастерных и спейсерных пластин для барреля адронного калориметра установки АТЛАС. Эта программа была разработана сотрудниками ОИЯИ для исключения значительного (более 1 % от однодневной продукции) брака в производстве абсорберных пластин.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна, 1998

Alikov B.A. et al. E13-98-135

ATLAS Barrel Hadron Calorimeter:

General Manufacturing Concepts for 300000 Absorber Plates Mass Production

We summarize 4 years (1994–1997) experience of design and research efforts led us to the solution of 2 important tasks of a principal significance for precision assembly of one of major elements of ATLAS, — its Hadron Barrel Tile Calorimeter. These tasks were:

— to develop the high tolerances (50–100 microns) technology for about 300000 units of calorimeter nuclear absorber plates mass production,

— to choose the best manufacturer(s) able to satisfy shop drawings demands in a reasonable balance with some other significant criteria: production period, price, acceptable geography location (transport expenses), available storage area and access ways, reliable quality control etc.

For the best absorbers producers our final choice was the TATRA PLANT (Czech Republic) for 1.6 m long plates stamping (40800 units) with Argonne punching die and the MINSK TRACTOR PLANT (Belarus Republic) for smaller size plates stamping (about 240000 units).

We exclude noticeable (more than 1 % of the day production) tolerances violations by the specially developed QUALITY CONTROL Program.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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