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POLISH ACADEMY OF SCIENCES

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113

Selected papers from the International Conference on *Turbines of Large Output* devoted to 100th Anniversary of Prof. Robert Szewalski Birthday, Gdańsk, September 22-24, 2003

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Transactions of the Institute of Fluid-Flow Machinery have primarily been established to publish papers from four disciplines represented at the Institute of Fluid-Flow Machinery of Polish Academy of Sciences, such as:

- Liquid flows in hydraulic machinery including exploitation problems,
- Gas and liquid flows with heat transport, particularly two-phase flows,
- Various aspects of development of plasma and laser engineering,
- Solid mechanics, machine mechanics including exploitation problems.

The periodical, where originally were published papers describing the research conducted at the Institute, has now appeared to be the place for publication of works by authors both from Poland and abroad. A traditional scope of topics has been preserved.

Only original and written in English works are published, which represent both theoretical and applied sciences. All papers are reviewed by two independent referees.

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Editorial

These Special Issues of the *Transactions of Fluid-Flow Machinery*, Nos. 113 and 114 contain selected papers from the International Conference on *Turbines of Large Output* devoted to commemorate 100$^{\text{th}}$ Birthday Anniversary of Prof. Robert Szewalski. The conference was held in Gdańsk, Poland on September 22-24, 2003.

The Conference is a continuation of previous conferences held at the Institute of Fluid-Flow Machinery PAS in former years dedicated to technology of steam turbines. Series of conferences bearing the same name took place in the years 1962, 1965, 1968, 1993. In 1997 organised has been a conference on steam turbines and related topics, but with a slightly amended title – *Problems of Fluid-Flow Machinery.* At present at the Institute of Fluid Flow Machinery there are conduced research of fundamental character encompassing both the issues related to steam turbines and fundamentals of power engineering.

Organisers of the present conference have returned to the traditional name, i.e. Conference on *Turbines of Large Output* to mark the respect to the memory of Professor Robert Szewalski (1903-1993), the founder and a director of the Institute of Fluid-Flow Machinery for several years, and initiator of the conference series devoted to the problems of steam turbines.

The Editors are very grateful to the referees of the papers presented in this issue of the *Transactions of Fluid-Flow Machinery*: J. Badur, W. Batko, E. S. Burka, J.T. Cieśliński, P. Doerffer, A. Gardzilewicz, B. Grochal, J. Kiciński, G. Kosman, T. Król, J. Krzyżanowski, J. Mikielewicz, A. Neyman, W. Ostachowicz, R. Puzyrewski, R Rządkowski, J. Świrydczuk, M. Trela, T. Uhl and Z. Walczyk.

We appreciate cordially the manifested authors interest in our conference. Special thanks are conveyed to Ms 'Maya' Bagińska, for her fruitful editorial help related to directing the papers to reviewers and correspondence with the authors of contributions.

Prof. Jarosław Mikielewicz
Editor-in-Chief

Dr Edward Śliwicki
Managing Editor

TRANSACTIONS OF THE INSTITUTE OF FLUID-FLOW MACHINERY

No. 113, 2003, 35-50

BOLESŁAW ŁUNIEWICZ[a], KRZYSZTOF KIETLIŃSKI[a]* and ANDRZEJ GARDZILEWICZ[b]

Experience of Alstom Power in large output turboset modernisations in Poland

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Abstract

The paper presents selected examples of ALSTOM Power experience in the scope of modernisations of large output turbine generator sets at Power Plants in Poland. Depending on turbine age and its wear degree and the other Unit devices as well as depending on financial resources and forecasted operation period of devices, the various scenarios of modernisation can be chosen. Turboset modernisation / retrofit effects are strongly depending on the depth and scope of reconstruction of main unit devices. Widely understood modernisation is one of the Polish power industry chances. The possibilities of turbine modernisation being able to be chosen and those already carried out by now together with their checking out by adequate measurements have been presented in this paper.

Keywords: Large output turboset modernisation

1 Introduction

ALSTOM Power Group is one of the most important suppliers of systems and services for power engineering all over the world. ALSTOM Power offer includes among others: "turnkey" Power Plants, gas and steam turbines, generators, boilers and environment protection systems. For past ten years, retrofits and modernisations of steam turbines became very important area of activity in Poland. Inevitable progressing process of ageing of devices, which are a core of power output installed in Power Plants as well as turbine technology development

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already recorded during the past 40 years have resulted in the new developmental possibilities within power engineering systems. The possible partial utilisation of existing infrastructure related to modernisation (rehabilitation) of Power Station permits for costs limitation and improves economical effectiveness of this solution in relation to installation of the new power output as a "green field" option. Utilisation of modern technologies by replacement of worn device elements with the new ones is resulting in a life time reconstruction and reliability increase of the turbine sets. In addition it brings a considerable increase of their efficiency. Steam turbine retrofits consisting in utilisation of the latest generation blade systems are leading to efficiency increase and the additional benefits related to power output generation increase or (what is particularly important in the Polish market conditions) the advantages being a result of fuel consumption (heat rate) decrease. The magnitude of effects achieved by Power Plant depends not only on difference of technology levels at present and those forty years ago but at the same time the effect value becomes additionally higher by removal of permanent ageing results already accumulated through all operation years.

2 130 MW turbine retrofits at Siersza Power Plant

In 1998÷2002 there has been carried out a rehabilitation (reconstruction) of 130 MW units at Siersza Power Plant in Trzebinia in Poland. In the first place a decision concerning the reconstruction came from expiration of lifetime reserve of the unit high-temperature elements and the necessity of essential decrease of fuel consumption rate and emission of pollutants as well.

The scope of modernisation particularly comprised:

- replacement of steam boilers with the new ones,
- replacement of turbosets with the new ones (turbines and generators),
- unit and detach transformers,
- replacement of main condensers with the new ones,
- unit control systems and turbine generator sets Instrumentation and Control (I&C)

At the same time it was possible to utilise between others the existing facilities:

- boiler and turbine island buildings,
- cooling towers and chimney,
- feed water tanks and deaerators,
- regenerative preheaters,

- pumps,
- lower foundation plates of turbosets.

As a result of analyses of various variants, the boilers based on CFB technology situated in existing pitch have been selected together with use of foundations and parts of existing boiler supporting structure. During modernisation of units Nos. 1 and 2, the live steam parameters (before turbine) have been increased from existing 125 bar / 540°C to 152.4 bar / 556°C and reheated steam parameters from 32 bar / 540°C to 36.7 bar / 556°C.

130 MW turbines of ALSTOM Belfort design were set into operation at Siersza Power Station in 1962. Until units operation has been stopped for modernisation, they had been operated appropriately for 36 and 38 years. They were three cylinder, condensing turbines with reheat, impulse blading and three flow exhaust of LP part. A single LP flow was an extension of IP part. In this case retrofit consisted in replacement of existing impulse turbine with a completely new, two cylinder, reaction turbine with reheat, designed for sliding live steam pressure operation. The new turbine with 16CK145 identification number (Fig. 1) was composed of standard elements of MT and RT turbine series of types. HP turbine has double shell casing. Two halves of inner casing split at the

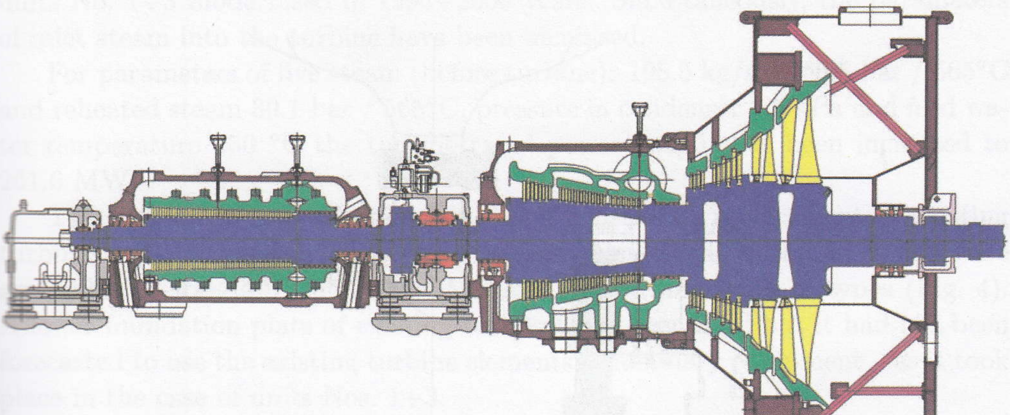

Figure 1. Longitudinal section of 16CK145 turbine.

vertical joint plane, are connected by means of shrink rings whereas outer casing halves (determined by a horizontal joint plane) are bolted with joint bolts. A steam into HP turbine is supplied from two valve chests screwed down on both sides of outer casing. Each chamber consists of one stop valve and one control valve. Steam flows through control valve diffusers into two adequately shaped half–spirals. This tangential steam admission ensures utilisation of inlet steam kinetic energy to maximum degree (Fig. 2). First stage of HP turbine is supplied

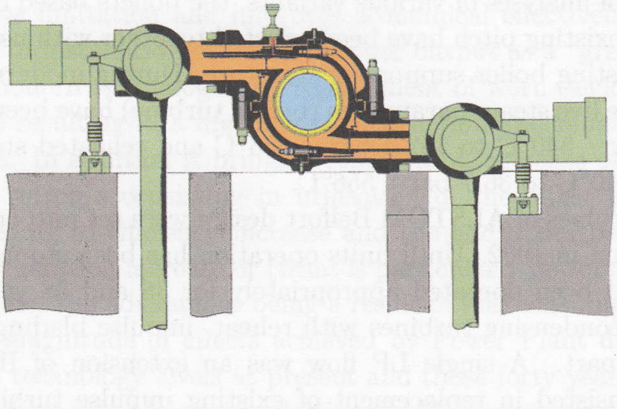

Figure 2. HP turbine steam admission system with spiral inlet.

with steam by means of half–spirals and is designed as radial–axial stage (Fig. 3). The new HP turbine beside the first stage includes additional 27 axial stages.

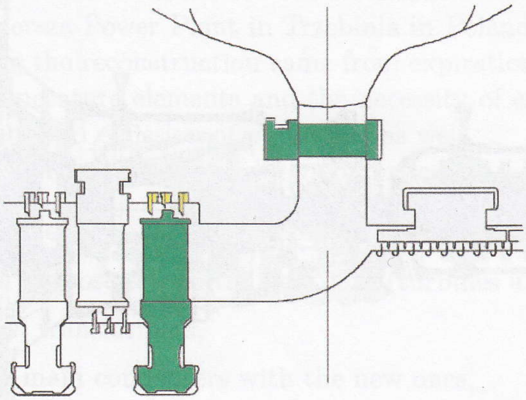

Figure 3. Radial–axial stage.

In the second turbine cylinder there have been IP and LP parts installed and coupled to each other. IP casing is of double shell kind. Inner and outer casings have been manufactured as castings of cast steel and nodular cast iron appropriately. Steam into IP turbine part is supplied in the same way as into HP part. The first stage is also designed as radial–axial one. The IP blading comprises 19 stages.

LP turbine is completely new, single flow with ND41 exhaust and is designed as standard module of MT series of types. The outlet surface of last stage equals to 8.9 m^2.

The outer casing welded of plates and stationary blades carrier made of nodular cast iron are split and bolted horizontal joint plane. LP turbine blading system consists of 7 stages.

Reconstruction of 130 MW units made possible to achieve a maximum power output increase from approx. 120 to 153 MW (i.e. about 27.5%) and decrease of heat rate by turboset by approx. 11÷15% to 7 866 kJ/kWh. Power output increase is partially a result of increase of boiler Maximum Continuous Rate (MCR) by approx. 10 kg/s (9.3%).

3 Retrofits of units Nos. 4 ÷ 6 at Turów Power Plant

In December 1999, the third phase of modernisation programme at Turów Power Plant including the units Nos. 4÷6 has been started. In connection with progress in circulating fluidised bed combustion technology it was possible to place the boilers with bigger capacity at the existing pitch than it was in case of units No. 1÷3 modernised in 1995÷2000 years. Simultaneously, the parameters of inlet steam into the turbine have been increased.

For parameters of live steam (before turbine): 195.5 kg/s / 166.5 bar / 565°C and reheated steam 39.1 bar / 565°C, pressure in condenser 6.5 kPa and feed water temperature 250 °C the turbine rated power output has been increased to 261.6 MW.

The turbine retrofit of units Nos. 4÷6 consists in replacement of existing turbines with completely new, three cylinder condensing turbines, which were assembled of standard elements of MT and RT turbine series of types (Fig. 4). A lower foundation plate of existing turboset has been used but it had not been forecasted to use the existing turbine elements or auxiliary equipment – as it took place in the case of units Nos. 1÷3.

HP turbine casing is of double shell type without steam extraction into regeneration system. Two halves of inner casing split at the skew joint plane, are connected by means of shrink rings whereas outer casing halves are bolted with joint bolts. Each of two valve chests consists of one stop valve and two control valves. The said valve chests are symmetrically screwed down at the both sides of upper half of HP outer casing (Fig. 5). HP blade system includes a control stage and 26 reaction stages.

IP turbine casing is of double shell type. Inner and outer casings are manufactured as castings of cast steel. IP turbine steam admission system design is conformable to ALSTOM Power standards and there is analogous to relevant IP

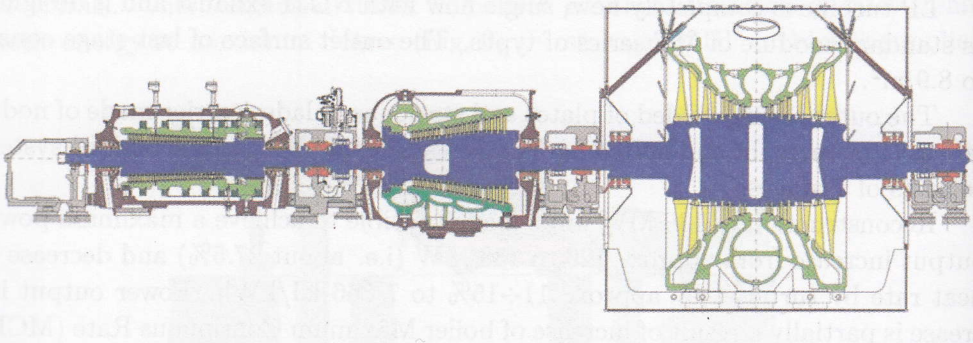

Figure 4. Longitudinal section of turbine at unit No. 5 after retrofit.

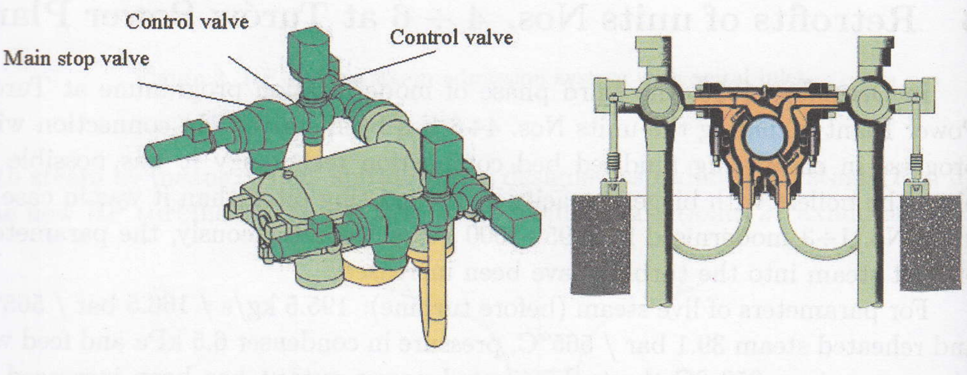

Figure 5. HP turbine steam admission system at unit No. 5 after retrofit.

turbines of units No. 1÷2 at Siersza Power Plant. IP turbine blading consists of 19 stages.

LP turbine is completely new, double shell, two-flow with ND37 exhaust and is designed as a standard module of RT series of types. Exhaust surface of last stage equals to 2×7.2 m^2. Outer casing is welded and inner one is cast of nodular cast iron and they are split and bolted at the horizontal joint plane (Fig. 6).

LP turbine first stages, which are supplied with steam by means of inlet spiral (Fig. 7) are manufactured as radial–axial stages with common stationary blade ring for the both flows.

The blade system of each flow consists of 6 stages. IP-LP cross–over pipe is designed as a single pipe with diameter of 1200 mm.

As a result of retrofit a decrease of turboset heat rate by approx. 19÷20% and increase of turboset power output by 76÷79 MW (i.e. 41%÷43%) has been achieved. Assessment of the achieved turboset power output rise must consider

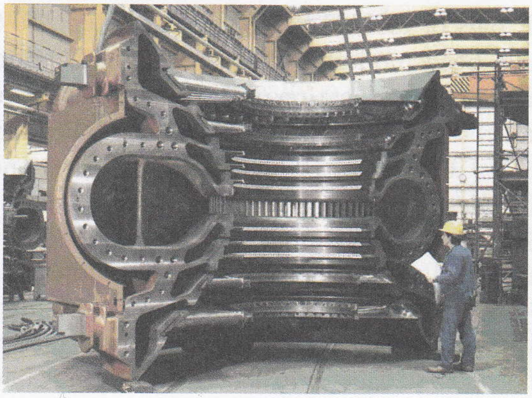

Figure 6. Inner casing of LP turbine.

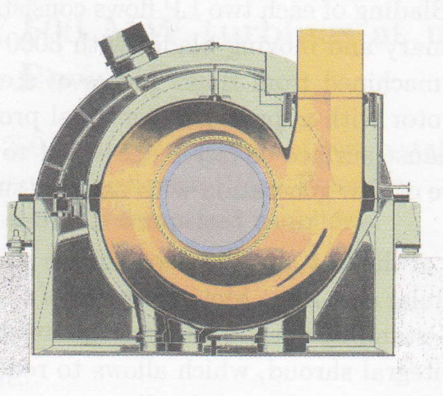

Figure 7. Inlet spiral of LP turbine.

the fact that it is partially related to live steam flow increase into the turbine from 157.3 kg/s for 195.5 kg/s (by 24.3%).

4 Retrofits of 360 MW turbines at Bełchatów Power Plant

Since the beginning of 1992 at Belchatow PP the activities have been undertaken in order to modernise the turbine island equipment. Initially, these actions concerned the oil and control system modernisation of 18K360 turbine. Among others, turbine hydraulic governors and LP steam dumping station controllers have been replaced with the electronic ones. In 1997 a realisation of modernisation program for LP part of 18K360 turbines has started. To the present moment the LP turbines have been modernized at eleven units. Completion of the last (twelfth one) LP turbine modernisation of Unit No. 2 has been scheduled for April of 2004. LP turbine retrofit (Fig. 8) comprises a replacement of blading based on a design from 60's (1000 series profiles) with the new one with considerably higher efficiency. The described retrofit consists in application the following new elements to the existing outer and inner casings:

- bladed carriers of stationary blading,
- welded rotor of drum type with reaction blading.

A middle carrier of stationary blades has been manufactured as cast steel casting whereas the front and rear carriers of stationary blades have been made of nodular cast iron. The new rotor shaft is welded of 4 forgings and original rotor shaft was welded of 6 forgings. Blading of each two LP flows consists of 5 stages, where first three ones have stationary and moving blades with 8000 series profiles and they are manufactured as machined from single pieces of steel bar. The blades are assembled on to the rotor with appropriate torsional pretwist. Original exhaust of D54 type with exhaust surface of last stage equal to 2×7.09 m^2 has been replaced by ND37 type of new generation with exhaust surface of last stage equal to 2×7.2 m^2.

Stationary blades of the last and the penultimate stage are manufactured as precise castings of nodular cast iron. Moving blades of the last stage are mounted on to the rotor as free–standing ones. The penultimate stage moving blades have been equipped with integral shroud, which allows to reduce leakage at the blade tip area in result of application of better sealing.

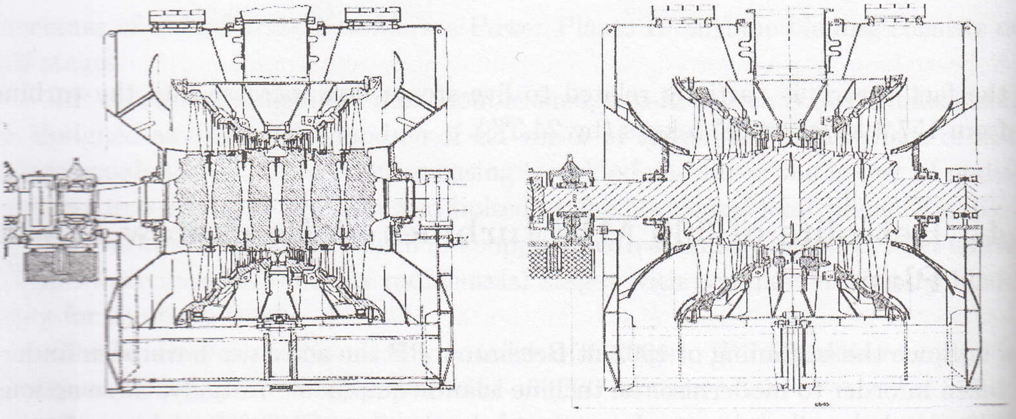

Figure 8. LP part of 18K360 turbine before and after retrofit.

LP turbine retrofits have allowed to achieve reduction of turboset heat rate by approx. 3÷4% and power output increase by approx. 10÷12 MW (i.e. 2.9÷3.5%).

Since the beginning of 1999, practically parallel to retrofits of LP 360 MW turbines there are modernisations (modifications) of HP turbine blading system carried on. These actions have a purpose to adapt real turbine steam flow rate in such a way that for maximum live steam flow rate – 316 kg/s and HP turbine Valves Wide Open (VWO), before stop valves pressure would attain rated value of 176.52 bar. Modification includes exchange of the following elements for new ones with lower steam flow rate: nozzle ring of control stage and stationary and moving blades of first four reaction stages. In result of already introduced changes an extension of expansion line in HP turbine part has caused the power output increase by 3.0 MW and reduction of turboset heat rate by 0.5%. Completion of HP turbine modification (HP turbine at Unit No. 10) is scheduled in 2004.

5 Retrofits of 500 MW turbines at units No. 9÷10 at Kozienice Power Plant

In the years 1997÷2001 a modernization of two installed K–500–166–2 turbines has been carried out at Kozienice PP in Poland.
The scope of modernisation has comprised as follows:

- HP turbine retrofit,
- IP turbine modernisation,
- LP turbine retrofit,
- modernisation of control system

Within a framework of HP turbine retrofit it has been used existing outer and inner casings and nozzle boxes. The following elements have been delivered as the new ones:

- control stage nozzles,
- rotor with reaction blading,
- stationary blade carriers,
- steam gland of balance piston,
- outer steam glands.

As an effect of HP turbine retrofit, its efficiency has been increased by approx. 12÷13%. HP turbine efficiency measured before modernization was equal to 75%.

The inter-overhaul intervals have been also extended and HP turbine lifetime

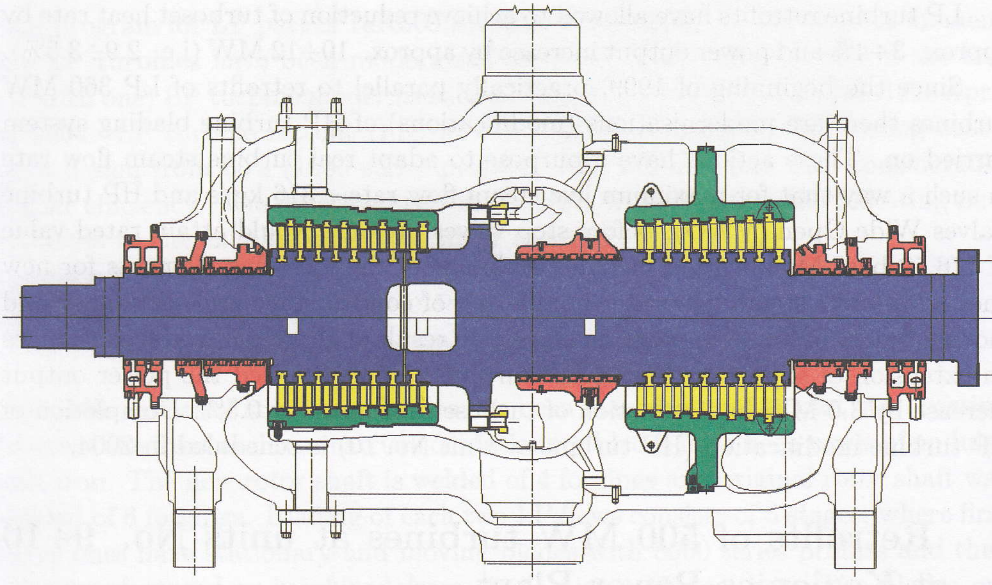

Figure 9. HP part of K–500–166–2 turbine after retrofit.

has been reconstructed.

Retrofit of LP 1 and LP 2 parts (Fig. 10) consisted in application of the following new elements:

- inner casings,
- welded rotors of drum type with reaction blading,
- bladed carriers of stationary blades,

into existing outer casings.

The new design bearings adapted to increased mass of bladed rotors has been used just as in the case of LP part retrofits of 200 MW turbines.

LP part efficiency attained during thermal measurements before modernisation was equal to 69%. Among others, LP part retrofit made available efficiency increase of this turbine part by approx. 18%, removal of limitation of minimum pressure in the condenser, extension of periods between overhauls, reduction of labour consumption during overhauls in result of higher life time of free–standing blades of last stages. After turbine retrofit its power output has been increased by approx. 11% and turboset heat rate has been decreased by 10%.

Modernisation of control and safety system has upgraded the control operation and also the said modernisation has adjusted the system to UCTE requirements.

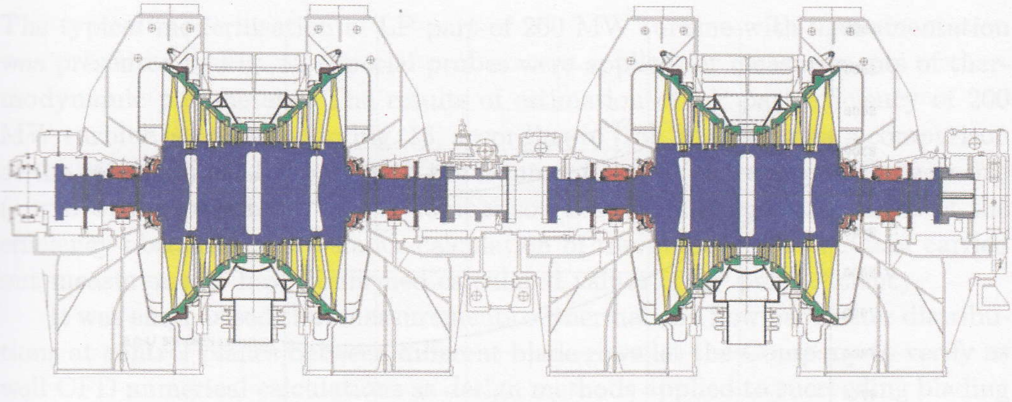

Figure 10. LP part of K–500–166–2 turbine after retrofit.

6 Some results of efficiency measurements of modernised steam turbines

In order to confirm advantages of the new turbine construction, the acceptance tests of turbosets before and after modernisation were performed [8-10]. They concerned first of all the efficiency assessment or specific heat consumption. These tests were carried out by qualified teams with international authorisation [11, 12]. It is very important that the efficiency characteristics of modernised turbine foreseen by ALSTOM Power were confirmed.

The some results of specific heat consumption measurements of chosen 200 MW and 500 MW steam turbines are shown in Fig. 11 according to [12]. The guaranteed values are indicated in this figure by dots.

These tests were completed by additional measurements of turbine cylinders, which were modernised. Main attention was focused on efficiency assessment of LP part. It is widely known, that this type of measurements is extremely difficult. The difficulties stem from the fact at that the expansion ends in the region of wet steam. Usually the efficiency of the LP turbines was estimated basing on investigations of heat balance with respect to all constituents of the turboset. Accuracy of the results of these estimations was very poor all the time. The situation has spurred investigations to develop reliable techniques of evaluation for this part of turbine. They have been mostly based on traversing the areas between stages for the measurements of thermodynamic parameters and the wetness. In this case sufficient accuracy has been estimated only for the model turbine under laboratory conditions.

It occurred that the LP Part efficiency could be determined in an approximate way, from measurements of the thermodynamic parameters and appropriate

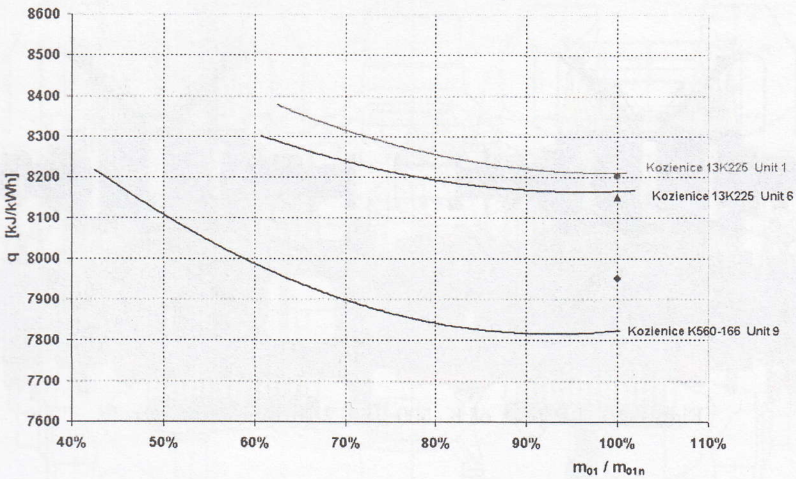

Figure 11. Specific heat consumption curves for 200 MW and 500 MW steam turbines after retrofit.

loss calculations. Such approach was presented for the first time by Moore [13]. A similar method has been developed at the IFFM Poland [14]. This method of efficiency assessment consists of:

- measurements of the distribution of temperature and static and total pressure along the blades at inlet and outlet of the stages in the region of superheated steam;
- measurements of distribution of total and static pressure and characteristic flow angles along the blades between the stages operating in the wet steam;
- calculations of the profile losses of the blading operating in the region wet steam;
- additional measurements of the circumferential distribution of pressure to control the flow symmetry.

For superheated steam the average pressure and temperature yield the efficiency directly. For wet steam the measurements of pressure and flow angles enable determination of exhaust losses including the tip clearance loss. It this case profile losses are calculated with help of a special CFD numerical codes, which was earlier validated on model and full scale turbines.

It can be assumed that for typical solutions of the LP turbines errors of efficiency assessment are two times lower than those related to conventional methods. This methodology was applied to verification of ALSTOM Power modernisation.

The typical modernisation of LP part of 200 MW turbine with instrumentation was presented in Fig. 12. Special probes were applied for measurements of thermodynamic parameters. The results of estimation of LP part efficiency of 200 MW turbine is presented in Fig. 13, according to [15]. In this figure a comparison of the results of old LP part with the Baumann stage (curve a) and the new one (curve b) are presented. For a comparison black circles indicate values of the efficiency obtained from balance calculation of thermal cycle. Results of carried out measurements have confirmed calculated values of LP part efficiency.

It was emphasised that measurements of thermal and flow parameter distributions at control planes between different blade rows let the Company to verify as well CFD numerical calculations as design methods applied to succeeding blading modernisations.

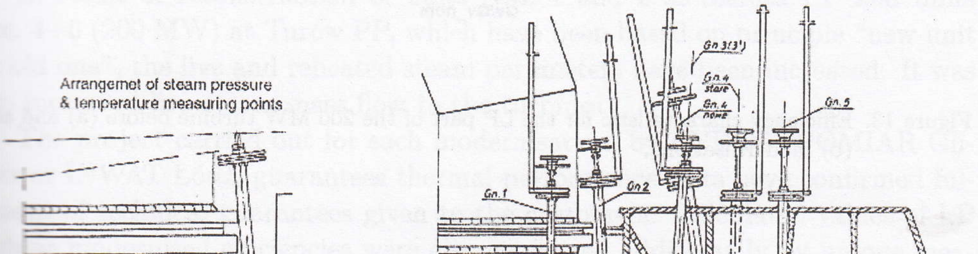

Figure 12. Test stand for verification of LP turbine retrofit with exhaust ND41 installed at Polaniec Power Station, Poland.

sively. The modernisation decisions have also different motivation (reasons). As far as in the case of relatively new equipment, with a sufficient lifetime reserve, the most often main goals of modernisation concern of heat rate reduction and power output increase – for the turbine sets, units as well as for old and hardly worn out power plants – a lifetime reconstruction comes to the fore.

Activities connected with unit lifetime reconstruction are mainly based on replacement of worn out elements with the new ones. As a consequence, it creates the new possibilities, removes many existing limitations and allows to achieve much higher effects in the range of turboset heat rate reduction and power output increase. These assumptions were confirmed during work already carried out at the Polish power plants. 360 MW turbine retrofits at Belchatow Power Plant and 500 MW turbine retrofits at Kozienice PP are classical examples of modernisations, which serve a purpose of increasing the efficiency and power output of the turbine generator sets.

In result of reconstruction of units Nos. 1 and 2 at Siersza PP and units Nos. 4÷6 (200 MW) at Turów PP, which have been based on principle "new unit for old one", the live and reheated steam parameters have been increased. It was also increased live steam mass flow to the turbines.

The project carried out for each modernisation, by ENERGOPOMIAR Gliwice or INWAT Łódź, guarantees thermal performance tests have confirmed fulfilment of technical guarantees given to the customers. Calculated values of LP turbine modernised efficiencies were also confirmed additionally by unique measurements, which were worked out by the Institute of Fluid-Flow Machinery of Polish Academy of Sciences in Gdańsk and carried out by Diagnostyka Maszyn. Flexible utilisation of opportunities, which are given by widely understood modernisation of turbosets is a chance for Polish power industry making available the for years operated power plants face a challenge of European electrical energy market.

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References

[1] Haller B.R., Hesketh J.A.: *Large steam turbine retrofitting to improve performance.* Proc. of Power Gen Europe Conf., Paris, May 1993.

[2] Kietliński K.: *Retrofits of LP steam turbines*, Proc. 3th Conf. PBEC, Warszawa 1997.

[3] Kietliński K., Michalowski W.: *500 MW LMZ turbine retrofit*, Proc. of COMPOWER 2000 Conf., Gdańsk, November 2000.

[4] Łuniewicz B., Karpiuk R., Stasik B.: *10 years' experience of steam turbine modernisation and retrofit activity at Elbląg works*, Proc. of JPGC'01, New Orlean, June 2001.

[5] Latva-Somppi J., Vaida V., Bugala G., Karpiuk R., Kietliński K., Stasik B.: *Upgrading power generation competitiveness in an environmentally friendly manner, Deva Power Plant Unit 3 Refurbishment*, Proc. of POWER-GEN Europe, May 2001.

[6] Łuniewicz B., Karpiuk R.,Stasik B.: *200 MW LMZ turbines–modernization and retrofit activity*, Proc. of ImechE Seminar on *Retrofitting Steam Power Generation Plant For Improved Performance*, London, September 2001.

[7] Łuniewicz B., Walkowiak R., Kietliński K.: *200 MW LMZ turbines modernisation at Turów Power Plant in Poland*, Proc. of Russia Power 2003, Moscow, March 2003, (in Russian).

[8] *Thermal Acceptance Tests of Steam Turbines Standard DIN 1943.*

[9] *Performance Test Code 6 on Steam Turbines ASME PTC 6-1996.*

[10] *Thermal performance verification tests of retrofitted steam turbines standard IEC 953-3*, Rules for Steam Turbine Thermal Acceptance Tests – Part 3.

[11] *Guarantee measurements of the turbines*, Reports of ENERGOPOMIAR Gliwice, 1999-2002, not published.

[12] *Guarantee measurements of the turbines*, Reports of INWAT Łódź, 1999-2002, not published.

[13] M. Moore, et. al.: *A method of measuring stage efficiency in operations wet steam*, Proc. of Int. Mech. Eng. C, 179/79, London.

[14] Gardzilewicz A., Marcinkowski S.: *Diagnosis of LP steam turbines prospects of a measuring technique*, PWR, Vol. 28, 1995, Joint Power Generation, Vol. 3 ASME 1995.

[15] Gardzilewicz A., Marcinkowski S.: *Flow tests in the LP section of 120, 200 360 and 500 MW turbines before and after modernisation*, Reports of Diagnostyka Maszyn Gdańsk, 1994-2002, not published.

[16] *Reference list of retrofits and 500, 360, 200 and 120 MW turbine modernisation*, ALSTOM Power Sp. z o.o. (in Polish).