A REFLECTION ON HOW THE DESIGN AND CONSTRUCTION OF WARRINGTON COMPRESSOR STATION WORKED IN PRACTICE 1988 to 2019

This article builds on the excellent paper by Charles Smith; British Gas Project Engineer for Warrington Compressor Station ("WCS") during the design and construction phase 1978/82 until the inauguration 1988, the reader is invited to read his paper at: http://www.oldflames.org.uk (please look under the history section).

Warrington Compressor Station 2021

Preface

Engineering Design has and always will be a combination of scientific theory, the various branches of engineering, legislation, industry rules and practical experience.

WCS was designed by British Gas Construction Department (aided by others) and followed this methodology. The designers had many known problems to overcome as well as attempting to predict future unknowns.

Post Inauguration: 1988 to late 1990's

A part of the gas National Transmission System ("NTS"), the station is located on Feeder 15 (the less direct route) which benefits from good all weather trunk road access and advantages regarding staff emergency response etc.

As more gas was exported from offshore Morecambe Bay in the early 1990's, Warrington Unit A&B started to accumulate increased annual running hours. Each gas compressor was capable of up to 21 Bar Differential Pressure ("DP") and flows of 40 MSCM/D (Million STD M^3/Day) boosting F15 pressure to a maximum of 70 Barg.

Unit	Gas Generator	Power Turbine	Compressor
A	RB211-24A	Cooper RT56	Cooper RF30 Single Impellor
B	RB211-24A	Cooper RT56	Cooper RF30 Single Impellor

The increase in running hours began to "shakedown" the machinery train. Problems developed with the Power Turbine ("PT") auxiliary drive gearbox (mechanical lube oil pump) on Unit B followed later by PT thrust bearing problems on Unit A. Due to long lead times and very bad winter weather, Unit B auxiliary drive was removed and temporarily blanked off. The AC standby electrical pump would provide all lubrication pressure, the drawback being a failure of incoming AC power would instantaneously trip Unit B. The station continued to provide compression to the NTS, with the benefits of connection to a reliable mains electrical supply and standby diesel 500KVa electrical generator being of particular importance.

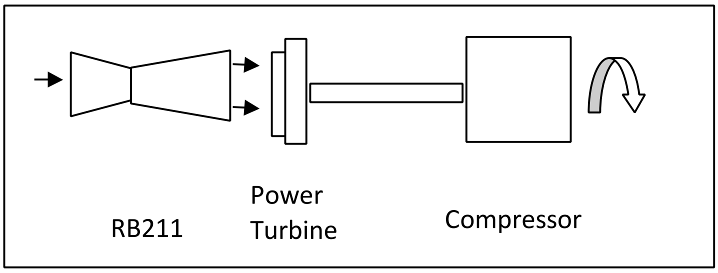
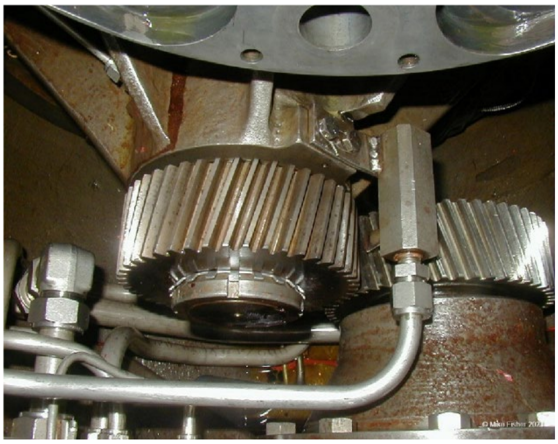


Fig 1



Auxiliary Drive (Partial Image)

Unit A, following extensive repairs to the whole Power Turbine thrust bearing assembly, was made available. Unit B gearbox was then repaired and returned to service.

Following the above, a complete auxiliary drive together with other, now designated strategic, spares were placed on stock.

A number of other drive failures occurred. These were associated with fatigue failures of the intermediate gearbox shaft, mechanical shaft/gear key failure and pump spline drive excessive wear. Solutions were installed in conjunction with the machinery supplier (Original Equipment Manufacturers (“OEM”)) to overcome many of the above.

The author has fond memories of visiting the OEM works in Liverpool; having always been made to feel welcome despite this authors Manchester roots.

Prior to the formation of Transco in 1994, responsibility for NTS compressor stations rested with Plant Operations Department as part of British Gas Headquarters, Production and Supply Division. Post 1994, this responsibility was geographically divided and passed to respective Local Distribution Zone (“LDZ”), these being constituent parts of the old regional gas structure e.g. North West Gas etc. The LDZ’s were poorly equipped to deal with turbo machinery issues. Some central technical support was created, but the needs of the UK compressor fleet were greater than the technical support available. Site staff pushed on with certain improvements such as installing two Dollinger RB211 lube oil console oil mist eliminators that resulted in notable reductions in oil use, saving thousands of pounds.

As gas flows from north to south through F15 increased, Warrington ‘moved’ more gas. The overall average F15 line pressure also increased. Due to this increased line pressure, the station’s ability to complete a unit start sequence decreased.

This increased gas pressure inside the centrifugal compressor, increased the axial force applied to the thrust bearing by the combined impellor, rotor and thrust collar assembly (Fig 1). This prevented the power turbine / compressor from rotating (failed to breakaway trip), even when the gas generator (RB211) achieved idle speed.

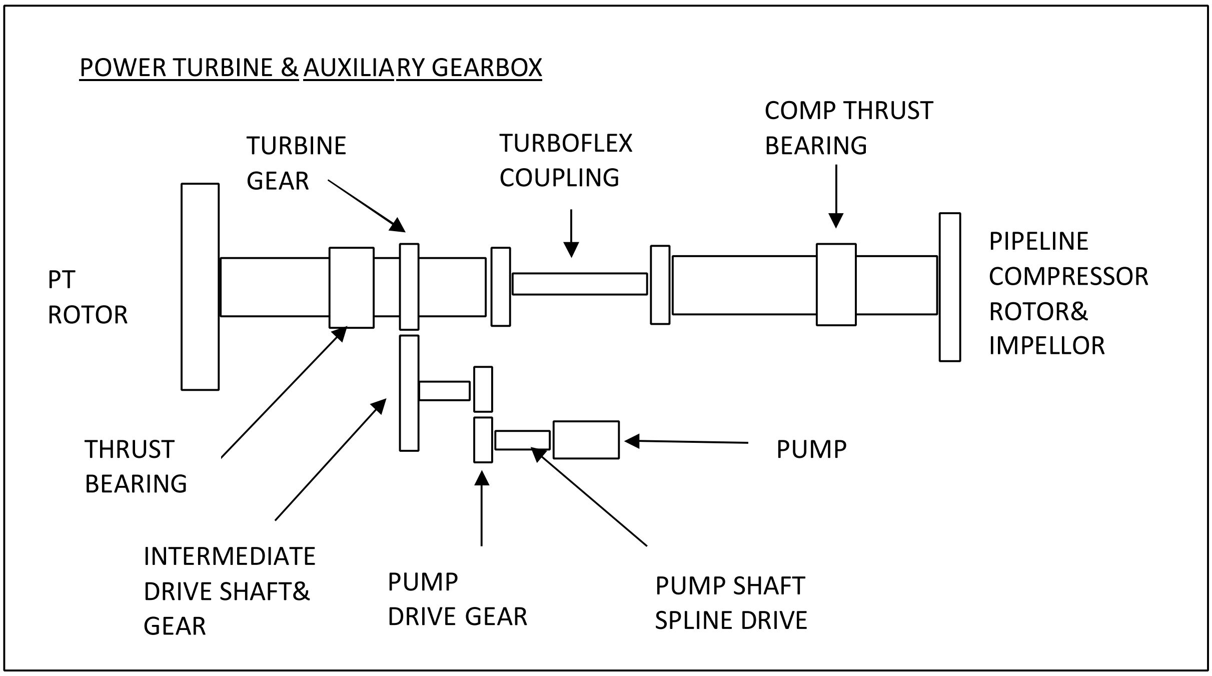


Fig 2

Warrington site staff and the OEM had been working independently on a solution to the breakaway problem, and a jacking oil system was designed and installed on Unit A. This system, operated only during the start sequence, applied high-pressure lube oil through an orifice drilled in each opposing thrust bearing pad within the compressor thrust bearing assembly, this forced the thrust collar away from the thrust bearing pads. The jacking oil arrangement resolved the power turbine / compressor breakaway problem.

1997 saw British Gas split into Centrica Plc and BG Plc. The creation, of the 'new' NTS, owned by BG Plc, resulted in responsibility returning (from LDZ's) to a centralised structure located at Hinckley, Leicestershire.

Following network analysis by the newly formed NTS, significantly more gas was forecast to flow down the west coast NTS, part of the so-called 'dash for gas'. The new NTS formed a construction department, albeit not on the scale of the previous 1980's department. Nevertheless, projects were developed to reinforce the NTS using the new and arguably controversial 'engineering for value' approach.

As part of the reinforcement, a second west coast feeder (F21) was constructed following a similar geographical route - the F15 AGI at Warrington became a multijunction for F15 and F21. In addition, analysis had indicated the current Warrington gas compressor design (21 Bar DP and 40 MSCM/D) would hinder the expected increase in flows, a gas compressor "re-wheel' followed, with a reduced DP of 15 Bar and an increased flow capacity of 60+MSCM/D. The jacking oil project was 'taken over' by the construction department.

Due to the reduction in impellor diameter of the re-wheeled compressor, there was a possibility the lateral force applied due to the increased line pressure (discussed earlier) would reduce (reduction in impellor area) negating the need for the jacking oil system. However, since the equipment had been purchased and the compressor was being dismantled, fitting the jacking oil system to Unit B made sense.

The "as built" 1980's compressor anti-surge valve arrangement (10" NB) had been flagged as a concern by site (insufficient valve diameter for re-wheel flow), however it was considered satisfactory by the construction department. Following operation of the re-wheeled machines, it became evident that further work would be required on the anti surge valves. These were subsequently replaced with valves 60% larger in diameter.

Both Unit A and B utilised a Halon type gaseous fire extinguisher system. However, following the introduction of the United Nations Montreal Protocol, and subsequent phasing out of ozone depleting Halon gases, the system was replaced with a Hi Fog water mist system.

2000 to 2010

BG Group demerged the UK Gas Transmission business, formally known as Transco, in year 2000 and named it Lattice Group plc.

The corporate structure changed again, Lattice Group merged with National Grid to form National Grid Transco in 2002, later becoming National Grid in 2005.

Warrington Centrifugal Gas Compressor

The site continued to operate as a base load site (10 months p.a.) for the Gas National Control Centre ("GNCC") when either Unit A or B would be on line, with changeovers to allow for gas generator washing.

As the decade progressed, the usual maintenance operations took place, mainly gas generator (RB211) overhauls and improvements such as the 24000 Hrs 7th stage IP compressor outlet guide vane ("OGV") ring being installed. This reduced the risk of OGV ring failure and increasing the time between overhauls. The batteries for the station emergency DC electrical supplies were also replaced.

Following inspection and the discovery of significant corrosion, both unit exhaust stacks were replaced with a Cullum Detuners turret arrangement.

The gas generator air intake two-stage filter system was replaced with a single stage bag filter colloquially known as 'teabags'.

The original Rolls Royce supplied Lucus gas starter motors were replaced with a Hilliard helical transverse type for starting the RB211 gas generator. Overhaul of the Lucas type became more difficult as the OEM could no longer support repairs etc. Due to the integrity requirements of such devices, third party repairs were not considered to be an option, hence adoption of the Hilliard.

Towards the end of the decade both Unit A and B control systems were becoming more unreliable, reducing start probability and MTBF. Site staff had pushed to secure an all-encompassing control system project, rather than a piecemeal approach, to improve reliability and safety compliance. The station, both units and the fire control system were included in the proposed scope.

As the replacement control system financial sanction papers progressed, a project to replace the control building roof and those on Unit A and B was pushed forward by site staff. It would have been foolish to install a new control system in a building with a failing 25year old flat roof.

Both in line station suction scrubber vessels (BS5500) where isolated, vented and purged to air to allow for confined space entry. Significant amounts of accumulated pipeline detritus were removed and a12 yearly PSSR inspection completed.

<u>2010 to 2019</u>

All the roofs were replaced. The control building utilised a slightly pitched insulated three layer felt system to prevent 'ponding'.

Early in the decade, once a long station outage period had been agreed, installation of the new control system commenced and incorporated many operational improvements to reflect newer thinking on process safety, human factors and operational reliability.

In order to reduce significantly the need to enter Unit A or B compressor buildings whilst in operation, video imaging and crucial additional instrumentation were installed, using transmitters rather than switches e.g. gas generator lube oil level indication, power turbine/compressor lube oil, seal oil tank level etc. Remote dynamic gas generator variable inlet guide vane ("VIGV") angle monitoring was also incorporated using a Rotary Variable Differential Transducer ("RVDT"); this facilitated VIGV angle against non-dimensional speed (N1/SQRT of ambient temp deg K) to be displayed 'live' on each unit control panel.

A new fire detection control system was also installed which further improved reliability.

During the long outage, Unit A and B 'temporary' in-line strainers (colloquially known as "witches hats") located in the pipework between the gas compressor and the 900mm unit suction ball valves, were removed. The strainers had been successful in preventing construction detritus from entering the gas compressor, however physical inspection of them was difficult, hence removal.

The gas generator (RB211) fuel gas system on Unit A and B was state of the art in the 1980's. Using a hydraulic actuated integrating fuel valve (Woodward TM55) with a close coupled Altair High Speed Shut Off Cock ("HSSOC") and an upstream 2" Fisher 310-32 fuel gas valve controlling gas inlet pressure to the TM55.

The Fisher 310-32 valve, located underneath the access grating running alongside the gas generators was, from a hazardous area ventilation perspective, poorly located (HSE: PM84 Control of safety risks for gas turbines used for power generation). The new arrangement for Unit A and B, designed with the operational input of site staff, improved the situation. An electrically powered Woodward GS16 fuel valve combined both the control actions of the TM55 and the Fisher 310 into the one valve. Two new electro-pneumatic HSSOC valves (manufactured by AMOT) were located immediately upstream of the GS16 to reflect the extra redundancy needed to reach the required safety integrity level ("SIL"). All components were located on a skid above the grating to allow easier maintenance and improved ventilation airflow.

Over time, small additions / improvements were made to: lifting equipment; permanent roof access; larger storage buildings; air conditioning; and domestic heating boilers.

Toward the end of the decade, gas flows on F15 & 21 changed, with very little gas being exported from Morecombe Bay. Greater flows travelled south via the eastern side of the NTS and LNG imports from Isle of Grain and South Wales travelled north and east respectively.

Warrington found itself at a "null point" on the NTS, consequently used sparingly by GNCC. Tightening of EU emissions legislation also resulted in both Unit A & B being limited to 500 Hrs p.a. in perpetuity.

Following a National Grid consultation exercise with various gas stakeholders including OFGEM, Warrington was deemed redundant and operationally closed in 2019.

Over the operational life of Warrington, both Unit A & B completed at total of approximately 80,000 hrs online without a significant process safety event.

Conclusion

Operational problems with turbo machinery are not unknown and can be difficult to eliminate at the site design stage, but this should not distract from a design that delivered arguably the best compressor station in the UK. The site proved an operationally valuable compressor asset and its design from an architectural and engineering perspective has stood the test of time. Having completed 30 years at WCS, the author is proud of his contribution to the UK's Critical National Infrastructure.