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AERODYNAMIC NOISE SOURCES IN INDUSTRY SESSION.

Experiences of Gilkes-Lincoln in the design and operation of pressure reducing and desuperheating equipment with particular reference to noise problems.

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SUMMARY

This Paper sets out to give an indication of the experience of Gilkes-Lincoln in the field of valve system noise and to give a brief statement of the current design philosophy.
It will be made evident that there is a scarcity of theoretical information available and that a pragmatic approach to valve system design is the only course available.

1. INTRODUCTION:

Gilbert Gilkes & Gordon have been in business since 1856, mainly in the field of water turbines and associated technologies. However in the early 1960's Gilkes decided to enter the high pressure and temperature valve field and set up a subsidiary Company known as Lincoln Valves Ltd, to design and market specialist valves and valve systems. The subsidiary Company, now known as Gilkes-Lincoln, has had considerable experience in the design of pressure reduction and desuperheating equipment due to the fact that the Company was set up to provide custom built equipment.

The technology of this type of valve application, is very difficult in that the whole realm of fluid mechanics is involved; from subsonic/supersonic flow, spray evaporation heat transfer and flow induced noise and vibration. The amount of useful theoretical work available is limited in each of the above fields and useful information on all the fields combined appears not to be available.

Therefore from this point of view the design of valve systems has to be approached from a combination of previous experience and intuitive reasoning.

At the present time, the Gilkes-Lincoln design concepts are at a stage which may be defined as Mark 5 and the purpose of this Paper is to describe the evolution of the Mark 5 design in relation to the Mark 1 version and to present some of the useful experience gained.

2. GENERAL DISCUSSION:

There are three main fields of steam valve application which are within the context of this Paper, namely pressure reduction in a pipe line without additional silencing, steam (valve centing) from superheater headers to atmosphere and steam bypassing of turbines either to a ring main or to a condenser.

Considering the relatively simple first type, i.e. straight steam pressure reduction, we use our standard patented Lincoln Valve design. In this design the flow path is axial and the roller element is in the subsonic flow regime, all sonic and supersonic flow occuring in the throat downstream of the roller. This therefore means that erosion and shock damage, if it occurs, takes place away from the moveable portions of the valve. If the shock system is within the confines of the valve then the noise emission is reduced due to the relatively thick pressure walls and the smooth flow path. Certain applications with higher pressure drops have, by necessity, a shock system which is outside the confines of the valve and hence the downstream pipework requires careful design.

At the present moment we have no noise level figures for these types of application and we presume that the noise levels associated with our valve design under these operation conditions (1800 psig inlet 250 psig outlet being typical) are satisfactory.

The second type of application is in the more arduous steam venting duty. For this case, steam at conditions of 2500 psia 1050°F is dumped directly to atmosphere. The requirement of steam vent systems is to be able to control the amount of steam being dumped and achieve this with a minimum amount of noise. This we accomplish by the use of our standard valve with a triple pass unit and consists of a valve and a three tube arrangement providing an efficient pressure loss system with a minimum length. Noise levels are considered as being below about 90 dB.

The current design of these units differs somewhat from the first versions in that the unit is shorter and the fabrication sequence and welding technology different due to experiences gained on attemperator units described in the nect section.

The third and final type of unit is the PRDS system where both steam pressure and temperature are reduced in one operation. This application covers a multitude of operation conditions, ranging from LP turbine bypass systems with inlet pressure up to 650 psig and exit pressure sub-atmospheric, through pass out turbine bypass systems with 1500 psig inlet and 135 psig outlet conditions to HP bypass systems with 2500 psig inlet and 50 psig outlet conditions. In the majority of cases the percentage of water injected is about 15 - 20% of the steam flow and hence the aerodynamic processes inside the valve/ attemperator are quite complex. For the LP turbine bypass the water quantities are however greater than this and approach 40 - 45%. Noise level measurements for the pass out turbine bypass units are once again of the order of 90 db although no reliable frequency/noise level information has been obtained. For these applications the background noise levels were of the order of 80 db and the apparent noise emission was at an acceptable frequency, i.e. not producing a very high frequency screaming noise.

With regard to the LP bypass systems, we are awaiting commissioning tests on these units to determine the noise levels.

Having now generally described the operating conditions of the three different typies of unit, the next section will deal with the general principles used by Gilkes-Lincoln in the design of the current units and the reasons for some of the design decisions.

3. THEORETICAL DESIGN CONSIDERATIONS:

If we consider the purpose of a pressure reducing and desuperheating system then the requirements can be simply written as:

1) Reduce pressure without erosion and vibration
2) Reduct temperature without erosion
3) Carry out these processes with the minimum of sound emission.

Since the majority of systems that Gilkes-Lincoln are involved in have pressure differences which produce supersonic flow regimes, it is reasonable to assume that the majority of pressure losses occur with shock losses and that in order to design a system with as low a noise level as possible, it is necessary to know where these losses occur. If the position of shock losses can be calculated, then the design of the system can be arranged to provide as much attenuation of the resulting noise levels as possible.

Taking an example of this method of approach, if we consider a pressure reducing valve on its own, then for a given pressure ratio it is possible to determine the area required downstream of the throat to produce a shock system to give the requisite downstream pressure. With a known downstream profile it is possible to determine the axial position of the shock from the throat and hence it is arranged that in this region the wall thickness surrounding the flow should be as great as possible.

This simplified analysis seems to work satisfactorily with the Gilkes-Lincoln valve due to its inherent venturi flow profile. However, it must be pointed out for the sake of completeness that this analysis neglects the effects of the boundary layer and non-ideal nozzle performance and also the effects of friction on the position of the shock. It is felt that these losses would tend to cause a movement of the shock wave towards the throat thus reducing the original problem.

If we consider the vent system as shown, then the above analysis could be applied to the valve component. The next problem is predicting the position of the shock losses in the triple pass unit. It is obvious that the valve will have sonic throat conditions and that the exhaust from the vent silencer will also be sonic but at a very much lower pressure. However flow conditions between these two points are somewhat indeterminate. Since these types of units have been in operation for a number of years and have operated satisfactorily without being an obvious source of noise, we must accept a pragmatic approach to the design of these units and accept that the knowledge of the aerodynamic processes inside a triple pass attemperator will probably elude us. Current units supplied at the end of 1971 have been designed along these principles and the only alternations in design between the original units and these are concerned with the method of fabrication.

The same sort of theoretical difficulties occur in the pipeline PRDS unit. The picture is complicated further however by the introduction of spray water into the supersonic flow immediately behind the valve throat. The effect of spray water on a supersonic flow of steam is not known but it is thought that the water evaporation causes a sonic throat to form immediately downstream of this injection point. The flow system will then tend to be similar to that through a vent system but with the advantage from the noise point of view that the flow velocity at exit from the attemporator triple pass unit is of the order of 200 ft/s.

Site evidence on these units indicates that noise levels are acceptable and that erosion damage caused by water injection

is almost non-existant.
The major problems with the early units was caused by fabrication design. Because these units have to have some form of axial expansion allowance for the tube and because flow induced vibration both from shock losses and general turbulent flow is prevalent, detail design of the fabrication must be to a high order. This we feel has now been achieved and hence no further problems should be experienced with these units.
An extension of the pipeline triple pass unit was designed as an L.P. turbine bypass system. As mentioned previously the spray water quantity for this type of application amounts to 40 - 45% of the steam flow and from this point of view the vessels were made in stainless steel. The aerodynamic design of these units was similar to that described previously with the exception that the discharge from the unit is radial and not axial. Since these units are fitted inside a condenser, radial discharge is required and since the surface area of the attemperator shell is limited, the last stage pressure drop is sonic with the flow issuing from a series of small holes. The internal aerodynamic processes are still somewhat unknown and the design has been based on previous experience and utilises the current fabrication sequences. Site experiences of the operation of this type of unit should be available in early 1972.
Bearing in mind the difficulties of predicting the position of the shock systems in the normal triple pass units, one experimental unit was manufactured for a particular application. This PRDS unit was designed to reduce steam pressure from 2500 psig to 17 psia and was designated as follows.
Since the flow quantity was relatively small the current triple pass attemperator could be used with some important aerodynamic design changes. The unit was designed as a multi-stage pressure loss system by using a 5 stage nozzle system. This required designing a series of sonic nozzles with expansion cones so that the shock waves would occur within the discharge cone. Since the expansion cones were within the confines of thick walled members, the resulting noise levels should be greatly reduced. Also by using this approach the flow between each stage is subsonic and hence turbulent flow induced noise should be reduced. Once again site experience with this type of unit should be available in early 1972.
The logical progression we feel from this type of unit is that designed to be used to dump 650 psia steam directly to a condenser. Using the design philosophy gained from the previous exercise, a linear multiple nozzle system was designed for this application with three nozzles in series and the fourth stage as a radial outward flow system through a series of holes. This design concept gives three shock systems enclosed by thick walled pressure vessels with the last stage as sonic orifice discharge through multiple orifices. It is thought that this system represents the optimum approach based on the information available at the present moment.

4. CONCLUSIONS:

As will be seen from the above discourse, the design of this type of equipment is fairly difficult due to the lack of reliable theoretical information. Therefore the approach that Gilkes-Lincoln have taken is based on previous experience and the gradual changes in design where this has been though necessary.
In the case of the vent systems, the units are now probably as developed as necessary whilst the PRDS field is more or less wide open to design innovation, since each unit tends to be designed to suit each particular application.