Advantages of Pulsation Damping for Hydraulic Driven Piston Pumps in Paste and Thickened Tailings Transport

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ABSTRACT

This paper presents the advantages of pressure peak damping in positive displacement pump applications that are subject to pulsatile flow and how this damping can be realised. The higher the pressure fluctuation, the thicker the pipeline wall has to be. By reducing the pressure fluctuation produced by the pump, it is shown that the lifetime of the pipeline can be increased, resulting in a substantial cost saving.

1 INTRODUCTION

The distances tailings and backfill material have to be pumped are increasing, so the necessary pump discharge pressures are getting higher. Over long distances the costs of the high pressure pipeline are often higher than the pumping system. For the economical success of a high pressure pumping system a long lifetime of the delivery line is essential. This paper presents the methods used to reduce the costs of the pipeline by considering the pulsatile characteristics of the pumping system.

2 REDUCTION OF PRESSURE PEAKS

The majority of slurries and paste like materials are non-compressible because of the water content. When using positive displacement pumps, the nature of the pumping action produces pulsatile flow. For example, the design principle of a two cylinder positive displacement pump results in a pressure drop in the delivery line when the valve is switching over from one pressure chamber to the other. This cyclical pulsation has a major influence on the lifetime on the endurance strength of the welding of a pipeline. The lifetime of the pipeline can be increased by reducing the pressure peaks created by the pumping action.

2.1 Principles

The basic design principles when selecting a high pressure pipeline are:

- Delivery lines must be rated for endurance strength.
- Due to corrosive and / or abrasive delivery materials a removal of steel in the pipeline must be compensated for by additional wall thickness.
- The higher the pulsation pressures, the higher the additional wall thickness of the delivery line must be.
- The weakest point is normally the welding connection between the tube and flange. This is valid for all DIN and ANSI flanges and the ZX high pressure coupling system (Figure 1 and 2).

Figure 1 ZX pipeline connection

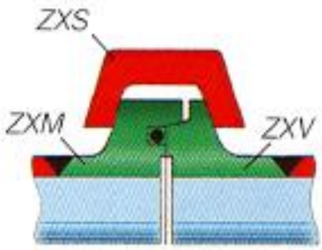


Figure 2 Welded connection

2.2 Effects of Pulsation

The behaviour of a delivery line among pulsating stress is as follows:

- The line issues noise and shows movements and load peaks in the bends.
- The higher the pulsation the higher the movements and dynamic load effects.
- Dynamic load effects are leading to cracks in the welding seams of the delivery line.
- A tool to prevent cracks in fixing points and welding seams is to test the delivery line components with pulsation tests.
- With this kind of tests a delivery line component will be overloaded cyclically until totally breakdown.
- With the test results the endurance stress can be calculated. Thereby, the endurance stress is the amount of load peaks which can be sustained a lifetime by the delivery line component.

2.2.1 Diagram of the endurance of the pulsation test of a ZX 200 pipeline

The endurance diagram explains the relationship between the existing pressure amplitude to the sustainable load cycles or reversed. The shown diagram explains additional the probability of a crack in a welding of a tube by difference load - resulting of pressure peaks and load cycles. For safety calculations it’s common to use the 0.1% line to achieve a safety degree of min. 99.9%. The shown diagram results of a pulsation test of a DN 200 pipe by two distinguish pressure amplitudes.

It has to be achieved, that the wear is the leading factor and not the numbers of pressure peaks. To reduce the numbers of switchovers does not only reduce the wear on the main wear parts of the pump, it also reduces the numbers of pulsations and their effects on the welding connections of the pipeline.

2.2.2 The advantages of pulsation damping

Condition: Pipeline 219.1 mm * 10 mm

Full seam butt welded

The positive effects of pulsation damping can be shown easily with an example.

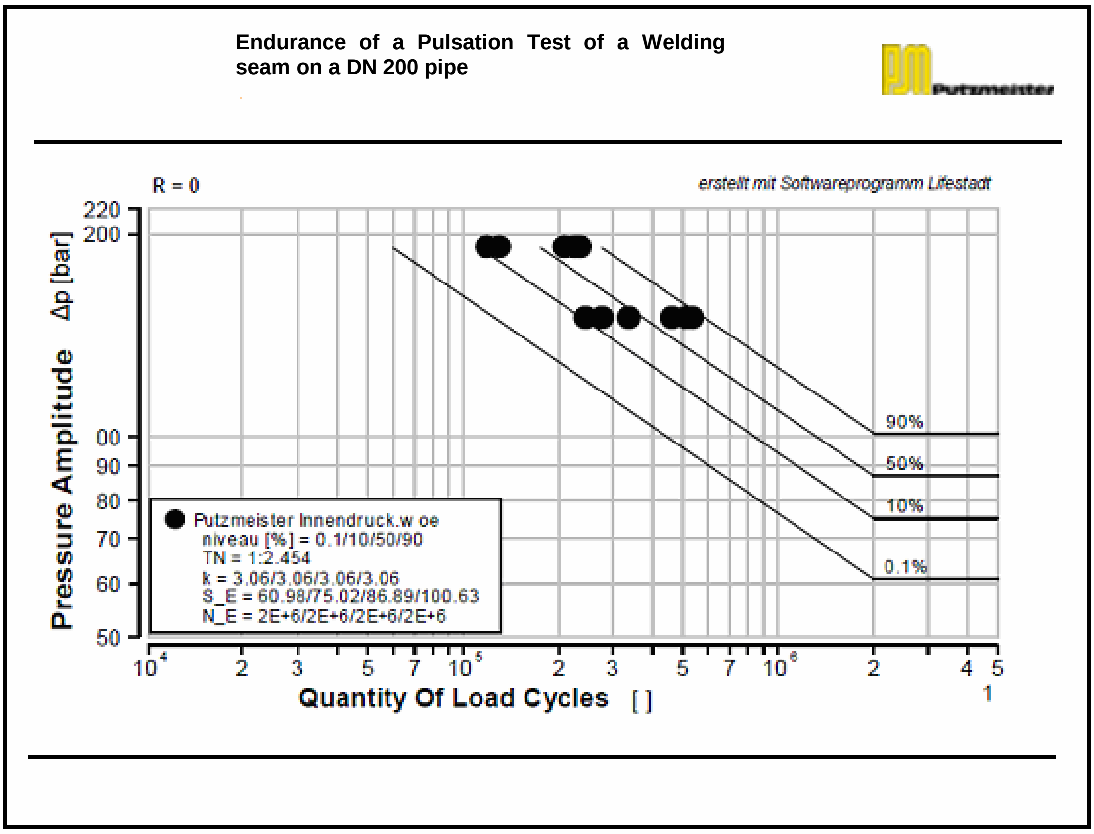


Figure 3 **Diagram of the endurance of the pulsation test of a ZX 200 pipeline**

In the left column of the following figure is shown a tube made of S355 (European steel quality) and measures 219.1 mm external diameter and 10 mm wall thickness. The maximum sustainable pressure is 110 bar by amplitude of 55 bar. This is the maximum allowed load cycle for full lifetime endurance without pulsation damping.

In the right column of the figure is shown the same tube but with pulsating damping which reduces the amplitude to 23 bar. The minimum pressure is higher 137 bar, the maximum 160 bar. That’s the result of the pulsation damping activities.

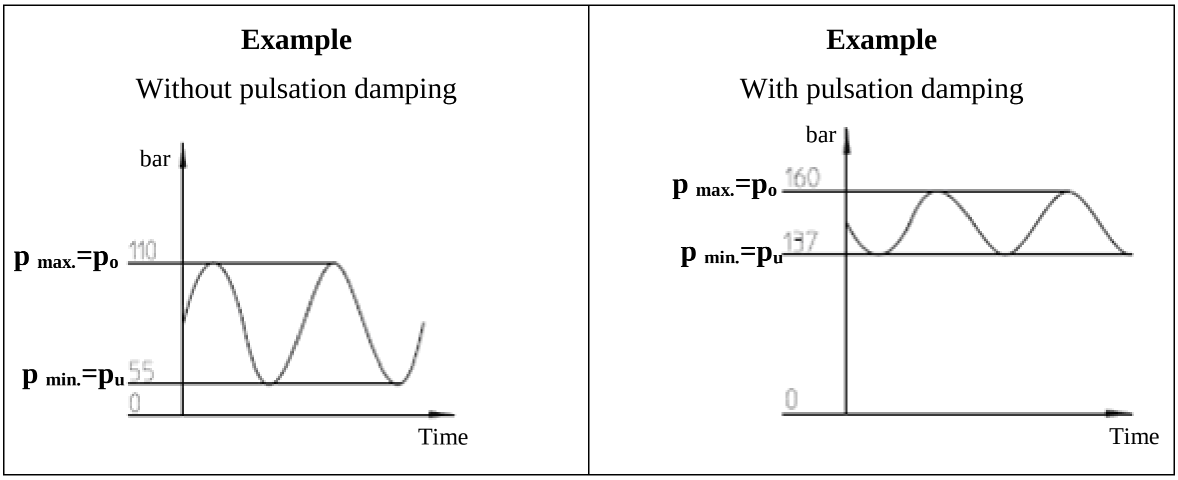


Figure 4 **Illustration of advantages of pulsation damping**

Results:

- Approx. 45% more pressure (p_{max}).
- Approx. 45% higher performance.
- Approx. 30% mass reduction (only 7.1mm wall thickness required).

2.3 How to Choose a Pipeline?

When selecting the delivery pipelines, elbows and couplings, the following issues have to be considered carefully:

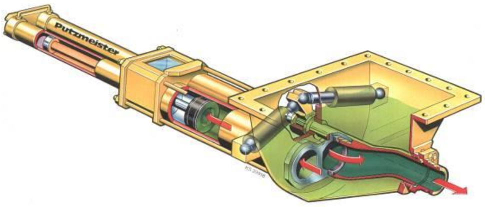
- The maximum pressure of the pump.
- The wear on delivery lines and couplings, which depend on:
  - Total flow rate.
  - Composition of the material.
  - Delivery pressure.
  - Speed of the paste in the pipe.
- Static pressure.

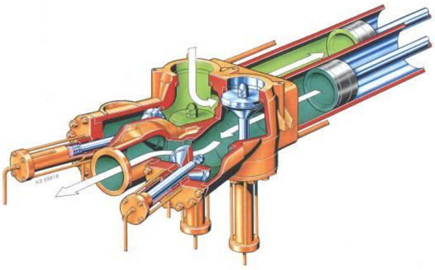
Underground paste distribution systems have the advantage that the gravity head in the shaft can be utilised to reduce the power requirements. For example, at Plutonic Gold Mine in Australia (Figure 5), the available pressure due to gravity is 100 bar, and at 100 m^3/h flow rate, this equates to a saving of 280 kW (assuming 100% efficiency) on the installed power.

Figure 5 Drill hole for the delivery line for backfilling at Plutonic Gold Mine

3 DIFFERENCES BETWEEN THE HYDRAULIC DRIVEN PASTE PUMPS AND THE PULSATION DAMPING SYSTEMS

3.1. Comparison between Oil Hydraulic Driven Piston Pump with Concrete Valve and Oil Hydraulically Controlled Piston Pump with Seat Valves





Concrete type pump

- For conveying coarse sludges or slurries with a high grain size content.
- Foreign bodies with a grain size up 100 mm can be conveyed.
- Pumping of flyash together with coarse bottom ash, as a thick paste or as a slurry.
- Cost efficient concrete like material can be produced and used for ground stabilisation and to produce a stable driving surface.
- Delivery pressure up to 120 bar.

Seat valve pump

- For conveying fine grained high density sludges or slurries.
- Suitable for liquids with abrasive components like mine water.
- Fine grained flyash, as a thick paste or as a slurry.
- Various chemical and organic high density solids.
- Delivery pressures up to 150 bar.

Figure 6 Stiff plastic concrete mix with a maximum grain size of 32 mm for backfilling

Figure 7 Fine grained backfill paste of Plutonic Gold Mine

In case the material is too thick to suck it into the delivery cylinders, a feeding auger can push it into the pump (Figures 8 and 9).

Figure 8 Coal paste from Siersza where a feeding auger is required

Figure 9 KOS pump with feeding auger at the coal power plant Siersza

3.2 How to Reduce Pressure Peaks by Pulsation Damping Systems

3.2.1 Concrete pump with no damping

The pulsation of a concrete type pump with S-valve without any damping systems during switchover is substantial, shown in Figure 10. During the switchover of the S-valve from one delivery cylinder to the other a short circuit between the pump hopper and the delivery line is created through the S-valve (Figure 11). Even when the switchover is very fast, a backflow of pumped material out of the pipeline into the pump hopper will occur and the pressure in the delivery pipe nearly drops to zero.

This is not recommended for a continuous mining operation, where the delivery line has to last very long as the pipe welding will be destroyed rapidly.

When the material to be pumped is very abrasive, the wear on the pipe is a major factor. This is the way a concrete delivery line on a concrete boom truck is calculated.

Note: The following diagrams are schematic only.

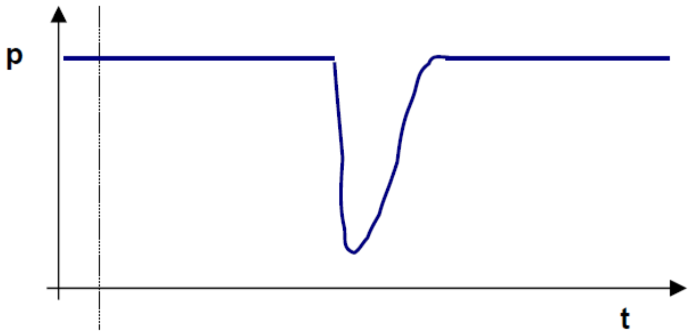


Figure 10 Pulsation of a concrete pump without damping devices

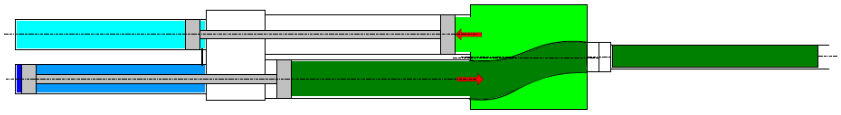


Figure 11 Schematic drawing of a concrete pump

3.2.2 Concrete pump with a check valve

To avoid the backflow in a concrete pump, a hydraulically activated check valve is mounted short behind the pump outlet (Figures 13 and 14).

When the delivery piston of one cylinder reaches the end position, the check valve closes and separates the hopper of the pump from the delivery line. The S-tube of the piston pump then switches to the other delivery cylinder. The pressure cannot release into the hopper of the pump. In this way the pressure in the delivery line is kept, even during the pump changeover phase. It reduces decompression knocking in the piping system and the pressure variation is much smaller, seen in Figure 11.

An additional advantage is that the pump switches over without pressure in the S-tube. This reduces the wear on the main wear parts, such as the spectacle plate and the wear ring.

With a hydraulically activate check valve it is possible to pump coal or other material into pressurised fluidised bed incinerators. These vessels push the material back with pressures up to 20 bar.

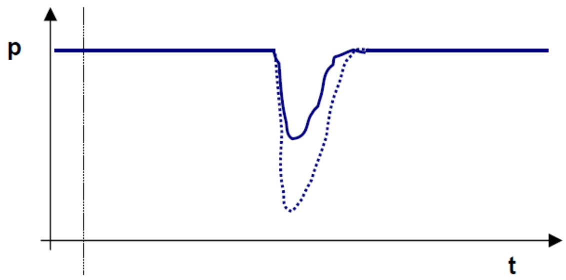


Figure 12 Pulsation of a concrete pump with a check valve

Figure 13 Schematic drawing of a concrete pump with a check valve

Figure 14 Paste pumping station at Walsum Coal Mine

3.2.3 Concrete pump with a check valve and a pulsation dampener

A High Pressure Dampener can be added to the concrete pump to further reduce peak pressures. This is the most efficient pressure peak damping system for concrete type pumps. The High Pressure Dampener is a small single cylinder pump which consists of one delivery cylinder and one hydraulic cylinder. It is driven and synchronised by the power pack and the control system of the pump.

The dampener is mounted into the pipeline (Figure 16) just behind the check valve on a T-piece into the delivery line.

During the pressure stroke of the delivery cylinder the dampener is filled with material out of the pipeline. Before the switchover the check valve shuts off the delivery line from the S-valve. This avoids backflow of the material. Simultaneously the dampener pushes material into the delivery line to fill the conveying gap during switchover. The direction of material flow remains. When the switchover is finished, the check valve opens and the piston pump starts to push the material into the pipeline again. The pulsation is very much reduced, as seen in Figure 15.

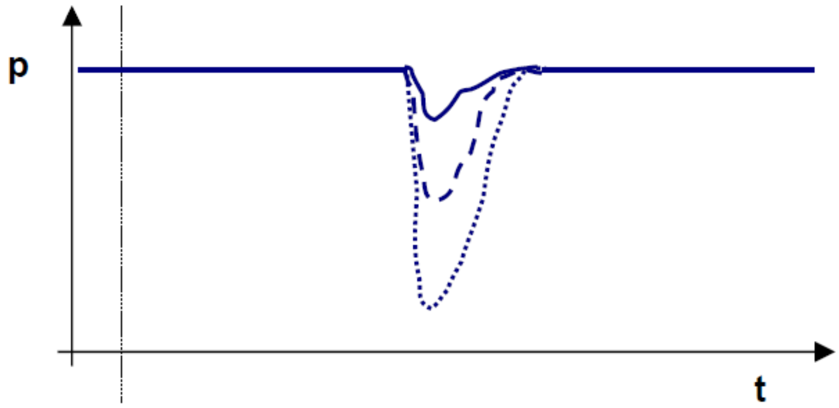


Figure 15 Pulsation of a concrete pump with a check valve and a high pressure dampener

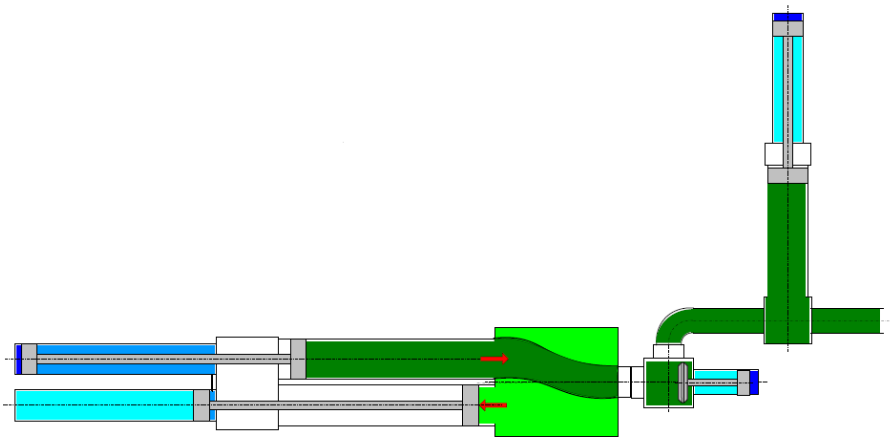


Figure 16 Schematic drawing of a concrete pump with a check valve and high pressure dampener

Figure 17 High pressure dampener mounted into a ZX 125 delivery line

3.2.4 Seat valve pump

The pulsation of a seat valve pump is much less than of a concrete type pump. There is no short circuit during switchover; the pressure in the pipeline is kept high.

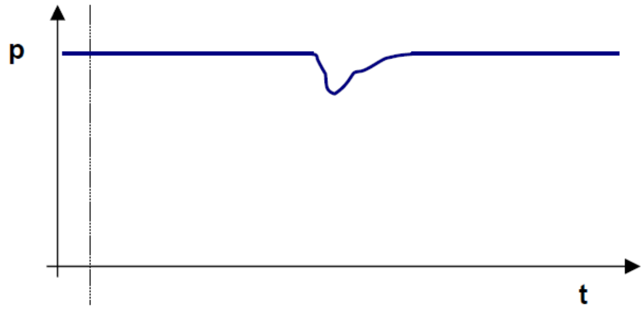


Figure 18 Pulsation diagram of a seat valve pump

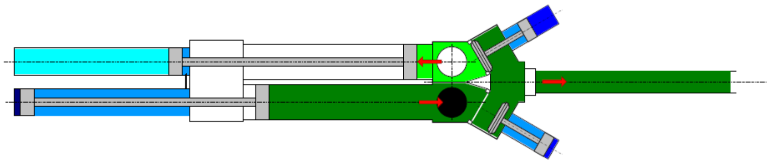


Figure 19 Schematic drawing of a seat valve pump

A fast switchover and no backflow reduce the pressure peaks during switchover. The seat valve pumps can be equipped with a High Pressure Dampener for a smoother operation (Figure 20).

Figure 20 Seat valve pump at Plutonic Gold Mine with high pressure dampener

3.2.5 Seat valve pump HSP with PCF (Pressure Constant Flow) system

The PCF can work with a hydraulic driven Duplex pump like at Lisheen (Figure 23 and 24) mine or with a Triplex piston pump. With a Triplex pump three single piston pumps are synchronised. During operation two pistons are always pushing the material into the delivery line. The third piston runs back a little bit faster than twice the speed of the pushing cylinders, changes direction and pre-compresses the paste in the cylinder and into the pump head. This is the stand-by position and at the end of the stroke of one of the other cylinders, when the pressure in the pipeline and in the head is equal, the piston starts to push the paste into the pipeline. A continuous material flow is achieved.

Using a Triplex pump for maintenance one piston can be taken out of operation. The machine works as a double piston pump with PCF. One piston always pushes the paste into the delivery line. This principle is shown in Figure 22.

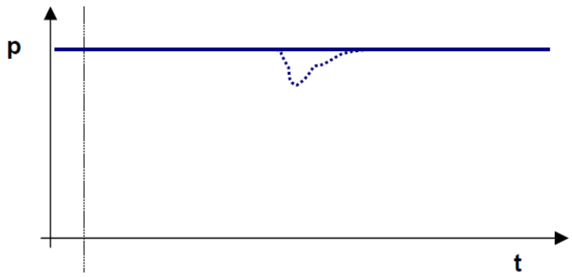


Figure 21 Pulsation diagram of a seat valve pump with pressure constant flow system

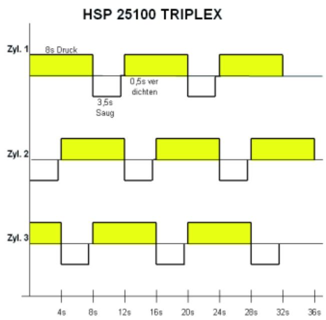


Figure 22 Working principle of a triplex pump

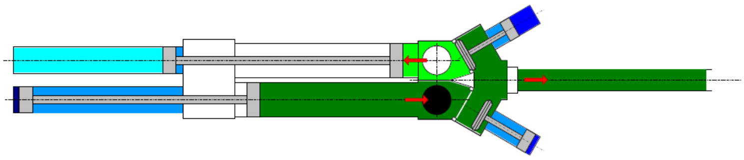


Figure 23 Schematic drawing of a HSP pump with PCF

Figure 24 HSP 25.100 double piston pump with PCF at Lisheen Mine, Ireland

The pressure reading diagram of Lisheen (Figure 25) show how small pressure variations with a pressure constant flow system can be. At a working pressure of 80 bar the pressure variations are smaller than ± 10 bar.

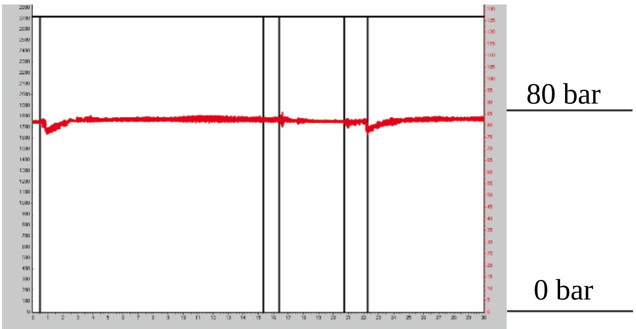


Figure 25 Pipeline Pressure diagram at 80 bar working pressure at Lisheen

Characteristics of the Pressure Constant Flow pump:

- No additional diaphragm or other mechanical parts with a limited lifetime.
- Reduces pressure peaks during the pump changeover phase.
- Provides pre-compression to reduce the gap in delivery which:
    - Ensures almost constant output flow rate.
    - Minimises water impacts, especially with slurries.

4 CONCLUSIONS

This paper has shown that pulsation damping is an important factor that will increase the lifetime of the delivery line as the fatigue loading is reduced.

The pipeline lifetime should not be limited by the welding connections and the reduction of the wall thickness by wear should be the only limiting factor.

The design load of the delivery line has to be in the range of the endurance strength as this is the basis for an economic and reliable pumping system.

ACKNOWLEDGEMENTS

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