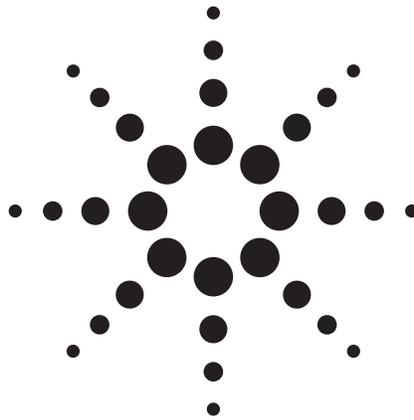


Testing 'R' type 2.5 Gb/s O/E and E/O devices in manufacturing

Product Note



OmniBER 725
communications
performance analyzer



Agilent Technologies

Introduction

Today, as networks become more dependent on optical transmission, the quality of the Optical to Electrical (O/E) and Electrical to Optical (E/O) components and converters is key to ensuring quality of service and network performance. These electro-optical devices have a range of complexity described by new terminology namely: 1R, 2R, 3R and 4R. Given their typical network applications, testing these is not simple, and requires specialised test equipment like the Agilent technologies OmniBER 725 communications performance analyzer.

The aim of this paper is to help the reader understand the operation of these device types, the typical manufacturing test needs for 2.5 Gb/s versions and how these test needs are easily met with the Agilent OmniBER 725.

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Key issues in O/E device test

There are a number of important considerations when deciding how best to test a specific O/E or E/O device in manufacturing:

- To test electro-optical communications devices and modules, by definition, you need to test at both optical and electrical (binary) interfaces with a range of telecommunications data rates and signal frame structures. Most test sets today only support E/E or O/O testing.
- The new standards, like ITU- T G.783 and G.825, for optical network regenerators in particular, require electro-optical components/devices to have very good jitter generation, jitter transfer and jitter tolerance specifications. For manufacturers to meet these specifications they need test equipment and systems that are able to measure these low levels reliably. The only way to achieve this is to use high quality test equipment which has very low jitter measurement noise (Intrinsic Jitter).
- High throughput on an electro-optical device production line can only be achieved if test times are short and test results are accurate and consistent. Accuracy is key to measuring specification margins in production. Inaccurate measurements lead to reduced yields, if good components are failed, and quality will be sacrificed if bad components are passed.
- Test Jig construction and interfacing can be critical when making Jitter and BER tests. This is especially important for devices with differential electrical inputs/outputs where cable lengths can give phase skew leading to inaccurate measurements.

The OmniBER 725 has been designed specifically for O/E and E/O test. It meets the requirements of all the above points offering manufacturing test capability virtually second to none. However, key to using the OmniBER 725 is understanding what is to be tested, the typical tests needed and how to perform these with the instrument.

'R' type devices have varied complexity and test needs

To be able to test a device it is necessary to know how it operates. Terms like '2R' and '3R' cover the most common electro-optical communications devices and it is necessary to understand their design to appreciate the test implications. By definition there are actually device types 1R, 2R, 3R and 4R. They are most often used when describing optical 'regenerators' but may also cover optical receivers in network elements eg. OADM's or OADM's. The 'R' stands for 'Recovery (sometimes also called Re-amplify)' or 'Re-shape' or 'Re-time' or 'Re-generate'. These devices may have single or 'differential signal' outputs or inputs eg. DATA and $\overline{\text{DATA}}$ (bar), CLK and $\overline{\text{CLK}}$ (bar) which may complicate test jig design.

The '1R' O/E (Figure 1.) device is the most simple variety and is a basic optical detector like a 'photo-diode' or 'photo-transistor'. It can only recover the pulse shape in electrical form from the optical signal. An example of this is the APD (Avalanche Photo Diode). The recovered signal will have all the distortion and 'noise' introduced by the transmission system eg. Laser 'chirp', fiber pulse dispersion and detector non-linearities plus electrical noise. Usually the detector is followed by an amplifier and hence sometimes the 1R device is referred to as performing 'Re-amplification' rather than 'Recovery'.

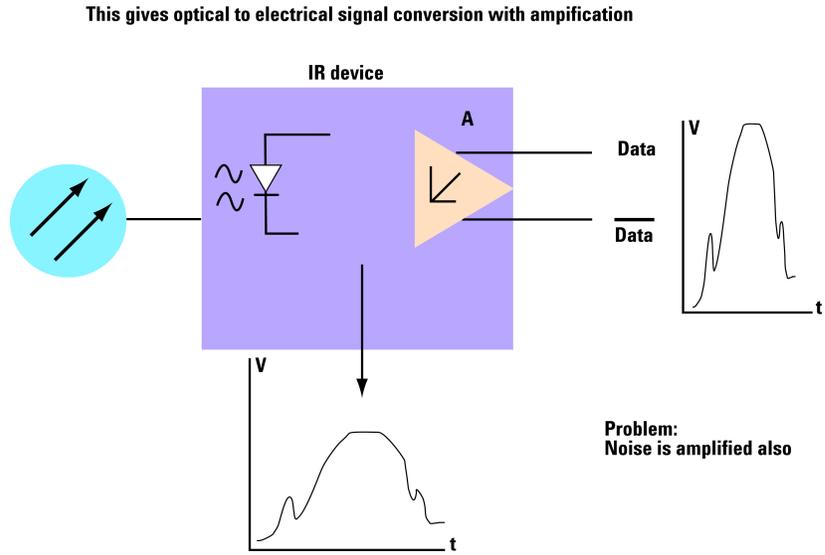


Figure 1. The '1R' device: Re-amplification

With the invention of Erbium Doped Fiber Amplifiers it is now possible to have a fully optical '1R' device. This is the ultimate goal for optical transmission system manufacturers as by eliminating conversion to electrical signals they can minimise noise making it possible to reduce the number of regenerators on long haul circuits eg. undersea cable systems.

The '2R' device (Figure 2.) is able to do recovery and re-shaping by having a non linear amplifier following the 1R device which may function like a threshold detector (comparator). The recovered signal has most amplitude noise removed but the reshaping process introduces Jitter as the original signals 'edges' are shifted by amplitude noise at the threshold detector.

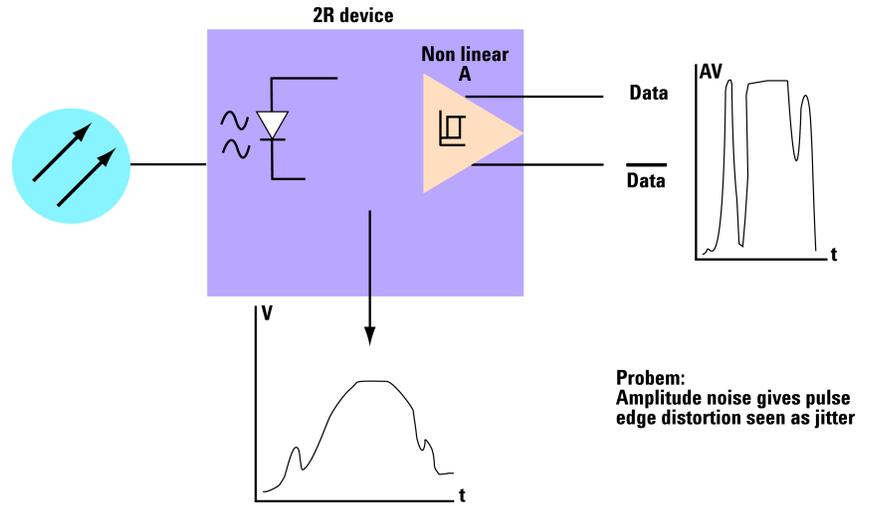


Figure 2. The '2R' device: 1R plus Re-shaping

Again it is possible to perform the 2R function optically using a non linear optical amplifier like a Mach Zehnders type laser. However these are still being developed and most manufacturers are still using electrical re-shapers.

The '3R' device (Figure 3.) is able to perform 're-timing' as well as the lower functions. To perform re-timing it has to include a Clock Data Recovery (CDR) circuit. A CDR circuit is based on a 'phase locked loop' and produces a stable clock source from the received waveform. The bandwidth of the Phase Locked loop is key to recovering the clock which is then used to re-time the outgoing data. The CDR has a filtering effect on Jitter but lower frequency components will remain.

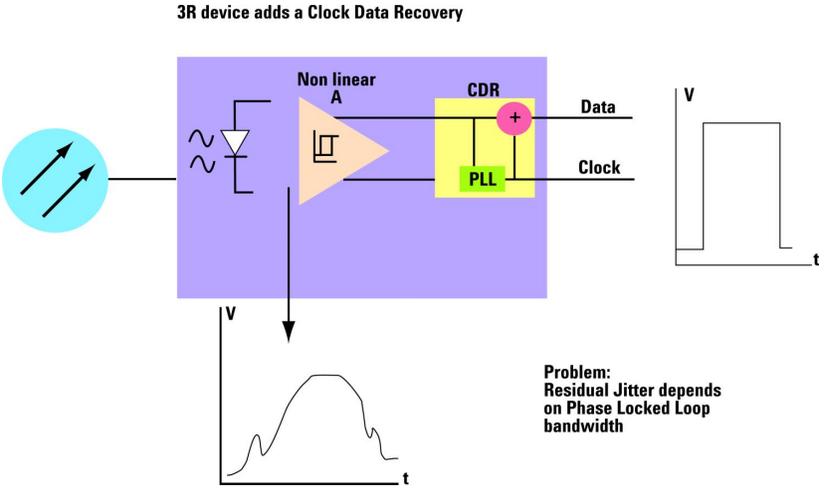


Figure 3. The '3R' device

The 3R device provides a higher quality output as Jitter is improved by the CDR however it is significantly more expensive than 2R types due to the increased complexity. For long haul fiber optic links 3R type regenerators are a necessity as the build up of Jitter limits the number of regenerators that can be cascaded before the error performance deteriorates below that specified in the standards.

The '4R' device is an extension of the 3R device and is able to optically retransmit the signal. This complete regenerator may also include wavelength translation. (See Figure 4.) Current research is attempting to produce an entirely optical version of this as it will minimise O/E conversions and associated signal degradation.

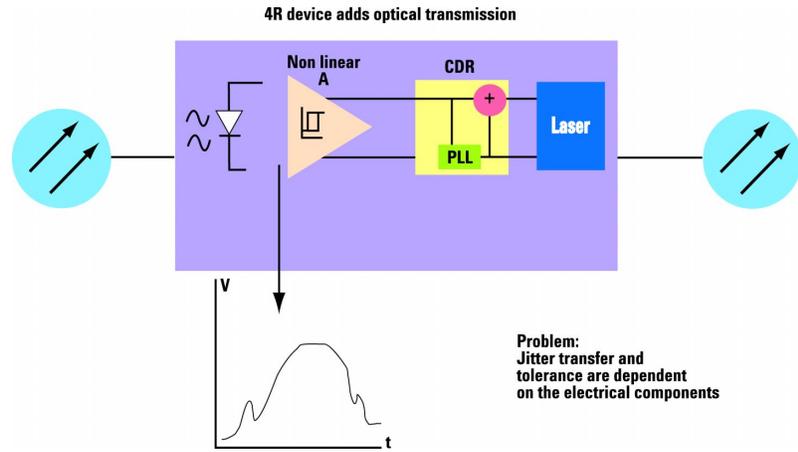


Figure 4. The '4R' device

Test jig construction can be critical to test accuracy

Depending on the semiconductor technology being used in the electro-optical device, connections can vary considerably and these need to be understood before considering test Jig design. The key considerations involve:

- **Single ended operation** – only a single output/input is available—usually a Non Return to Zero (NRZ) signal although RZ (Return to Zero) is also possible.
- **Differential Inputs/Outputs** – where both data/clock and inverted data/clock ports are available. This design improves noise immunity and is preferred for more sensitive higher cost devices eg. 2R and 3R.
- **AC or DC coupling** – DC coupling can introduce unwanted DC offset. This offset will affect pulse shape and can lead to degraded error performance by causing vertical eye closure (see Figure 5). AC coupling is more popular as it avoids this issue.
- **Voltage Offset** – with some semiconductor technologies the input or output signal must be biased to center around a specific voltage. Interfacing circuitry will have to match this to avoid reduced measurement accuracy through vertical eye diagram closure (see Figure 5).

- Signal phase relationships** – especially for 3R devices with differential outputs it is critical that all signal path lengths are identical to avoid measurement inaccuracy due to phase ‘skew’. At 2.5 Gb/s the pulse period is 400ps. 1cm of cable will give approx 100ps of phase change. Phase skew will in practice cause horizontal ‘eye’ closure (see figure 5.) causing innacurate BER and Jitter measurements. If the device to be tested has differential inputs the cabling, and possibly switching devices, will need careful design.

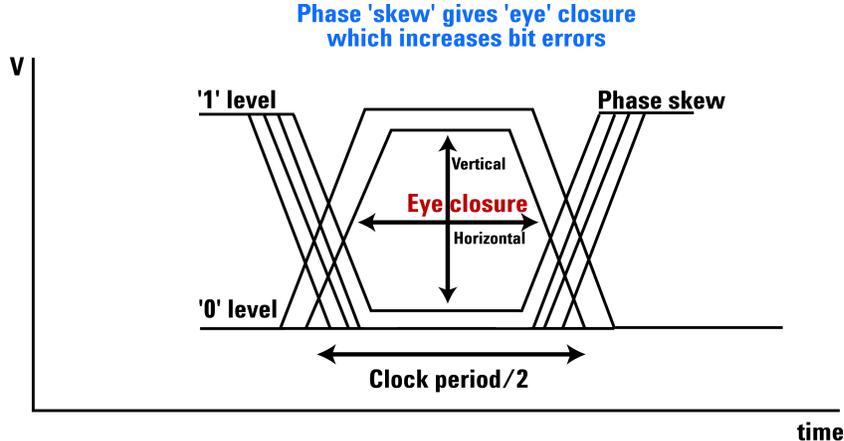


Figure 5

New standards involving jitter performance are the most difficult to meet

For transmission systems there are many standards that need be met. Where the optical device is being used as a ‘regenerator’ there are ITU specifications covering BER and jitter tests. The key specifications are ITU-T G.783 and G.825. As an example, for Jitter Generation, the G.783 specification requires 2.4 Gb/s devices to have less than 100mUI pk-pk and 10mUI RMS jitter output. More complex measurements like jitter transfer and jitter tolerance require conducting tests at many different levels and frequencies of jitter. This is usually combined into the concept of a ‘mask’, as in the example shown in figure 6., where devices must record values inside or outside the ‘mask’ to pass.

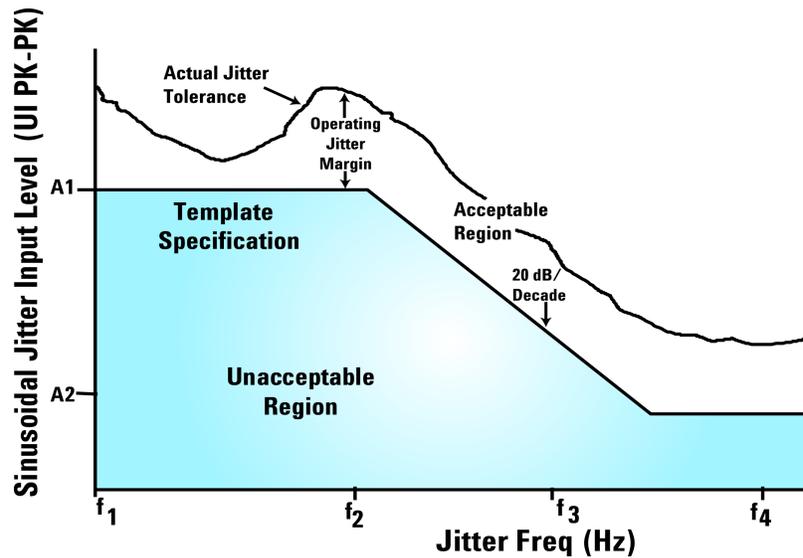


Figure 6

Understanding the test equipment requirements helps maximise production throughput and quality assurance

Test equipment in a manufacturing environment must have four key attributes:

- **The remote control is easy to use**

Test speed relies on having a test system controller. Programming the controller to sequence through the required tests must be straightforward and fast. The OmniBER 725 is ideal for this purpose as it uses the concept of 'Universal Instrument Drivers' and has a simple to learn 'SCPI' command set.

- **A high proportion of test results can be obtained in parallel**

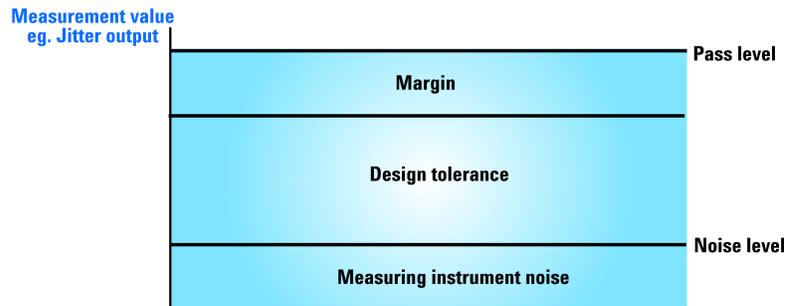
Many test sets need to sequence through each measurement. Others are able to perform many of the tests simultaneously reducing device test time considerably.

- **Jitter tests are performed quickly**

Jitter tolerance and jitter transfer tests involve checking device performance over a range of jitter frequencies and amplitudes. The speed at which the test equipment can change jitter transmitter output and the output to stabilise is key to performing jitter tests quickly.

- **Measurement accuracy**

Only by having accurate measurements can you establish your design margins. If you cannot measure accurately you risk failing good components or even having to over design them purely to counter the test equipment problems. This can be very costly for either case. In the example in Figure 7. you can only meet the specification for jitter output if the sum of the test set 'noise floor' (intrinsic jitter) and design tolerance is less than the 'pass' level.



To have a margin the measuring instrument noise and design tolerance must be at least be less than the pass level

Figure 7. The effect of accuracy on establishing 'margins'

The OmniBER 725 meets all these requirements providing the user with a highly affordable efficient solution for manufacturing test needs.

Setting up typical test jig configurations and tests using an OminBER 725 for each of the 'R' device types

Testing the 1R device

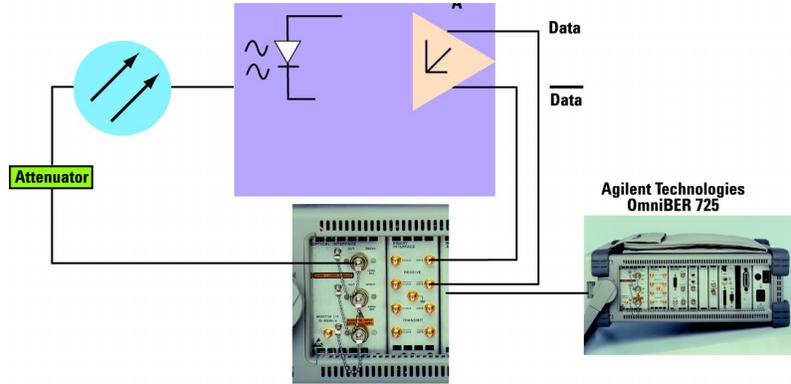


Figure 8. Testing the '1R' device

As this consists of a detector and amplifier it purely gives an amplified version of the optical pulse shape. However amplitude noise is also amplified which will reduce BER test performance. How to connect the Agilent OmniBER 725 test connection to this device is as shown in Figure 8. This may have both DATA and $\overline{\text{DATA}}$ outputs depending on the amplifier design.

Tests to perform are: BER, jitter output*, jitter transfer, jitter tolerance and optical sensitivity. To test optical sensitivity a variable optical attenuator is inserted into the optical transmitter path.

Testing the 2R device

This device includes a re-shaper function. This improves amplitude noise but introduces Jitter. The typical set up is as shown in Figure 9.

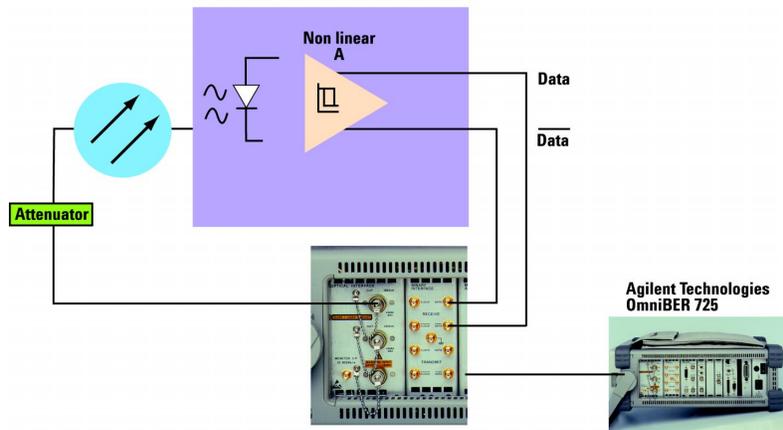


Figure 9. Testing the '2R' device

* *OmniBER 725 analyzer is able to do jitter measurements on Clock/Clock only.*

Tests to perform again include BER, jitter output*, jitter tolerance, jitter transfer and optical sensitivity.

Testing the 3R device

This device has the added complexity of a Clock Data Recovery circuit. This combination removes both amplitude noise and higher frequency Jitter. However depending on the bandwidth of the CDR there will be lower frequency Jitter. The test configuration is as shown in Figure 10.

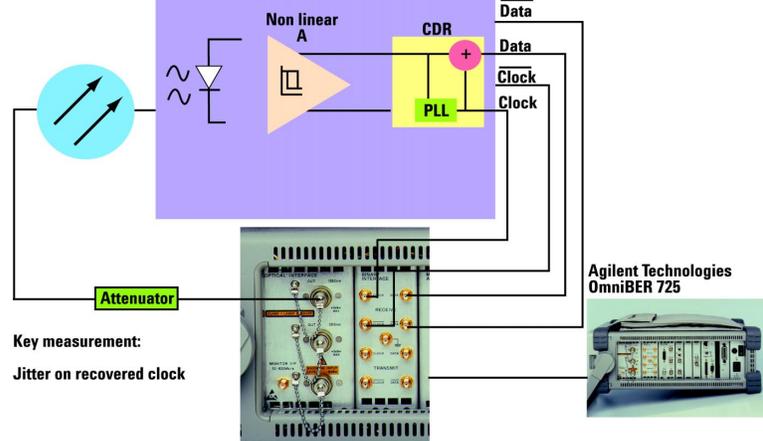


Figure 10. Testing the '3R' device

Tests to perform again include BER, jitter output*, jitter tolerance, jitter transfer and receiver sensitivity. Test jig cabling for 3R devices test is critical. All cables must be the same length to avoid phase variations which will affect error performance.

Testing the 4R device

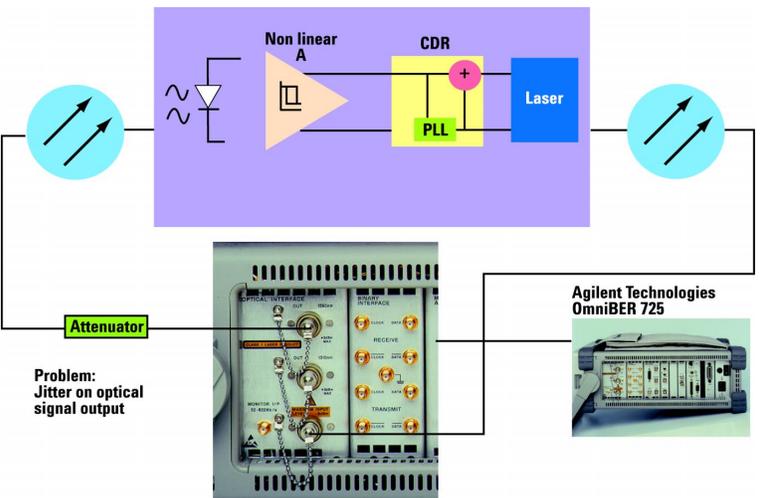


Figure 11. Testing the '4R' device

* *OmniBER 725 analyzer is able to do jitter measurements on Clock/Clock only.*

This is in reality an optical regenerator. The 4th stage is a laser device able to transmit the received pulses at whatever wavelength is needed. The Jitter performance of the 4R device is key as this limits the number that can be cascaded before error performance degrades below the requirements in the standards. A typical test configuration involves only optical connections as in Figure 11.

Tests to perform again include BER, jitter output, jitter tolerance, jitter transfer, optical receiver sensitivity and optical output power.

Conclusions

Optical communications relies heavily on electro-optical devices to transmit, regenerate and receive data. Today virtually all optical network equipment uses intermediate electrical stages. The industry has coined a specific method to classify these electro-optical devices which needs to be understood if test needs are to be met successfully. These test needs can only be realised using tailored test solutions, like the Agilent Technologies OmniBER 725, which have been designed for this specific application and will ensure maximum through-put with the highest possible quality assurance.

Notes

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