Investigation into the cause of the leakage of a tank wagon filled with Acrylic nitrile on 20 August 2002 in Amersfoort

Contract-issuing party: Council for Transport Safety

Reference :

Reference no. : AEAT/02/2600084/004

Report : P.A.A. Slob

Investigation : P.A.A. Slob and W. Plantagie

Project number: 2600084

Date : November 2002

Contents

1 Introduction

Following the leakage of a tank wagon number 33907865021-9 containing acrylic nitrile on 20 August 2002 in Amersfoort, the Council for Transport Safety asked AEA Technology Rail BV to carry out the technical investigation into the cause of the leakage.

The wagon in question was a liquid tank wagon with top discharge. On tank wagons of this type, there are no openings or appendages below the liquid level in the tank walls, see photograph 1.
The appendages for filling and pressurised discharge of the tank wagon are mounted on the top of the tank wagon. During the transport of toxic substances, these appendages are protected with a lockable cover.

Photograph 1: the liquid tank wagon on which the leakage occurred.

There are 3 openings on this tank wagon; the central opening with the red blind flange and ball valve discharges into the riser tube, which reaches to the ground, see figure 1 and photograph 2. By applying gas pressure to the tank, the tank can be discharged via this riser tube. The pipe can also be used for filling the tank.

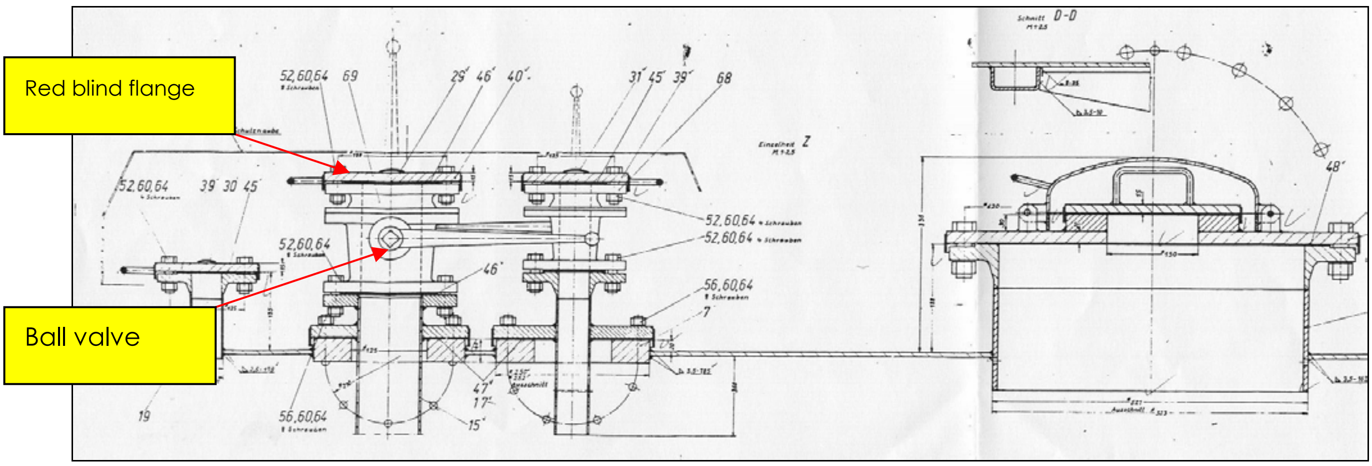


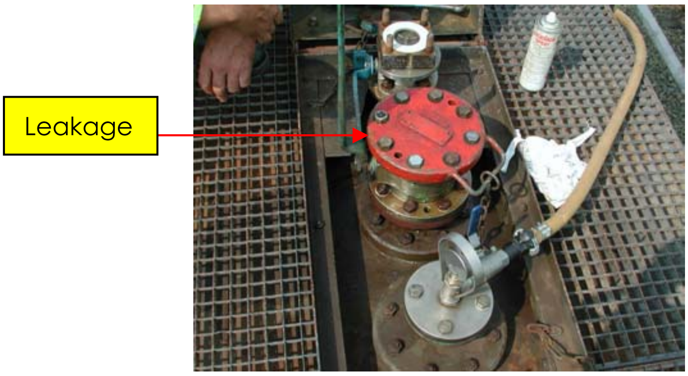
Figure 1: drawing of the appendages on the top of the tank.

The two other openings, sealed with blue blind flanges, are used for applying pressure to the tank wagon, to permit discharge via the riser tube, and for filling or sampling.

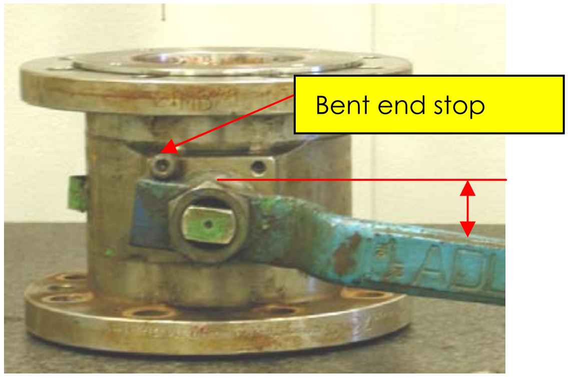
1.1 Facts as determined by the emergency services

Following reporting, it was determined by the emergency services in situ that the red blind flange on the valve of the filler pipe had leaked, see photograph 2.

The handle of the ball valve beneath the red blind flange was not in the horizontal position (horizontal is closed) but had been turned slightly further downwards, see photograph 3. The handle could be pushed further, because the end stop was bent, see photograph 4. Further investigation by AEAT Rail BV showed that the material beneath the end stop (M8 bolt) is deformed, see photograph 5.

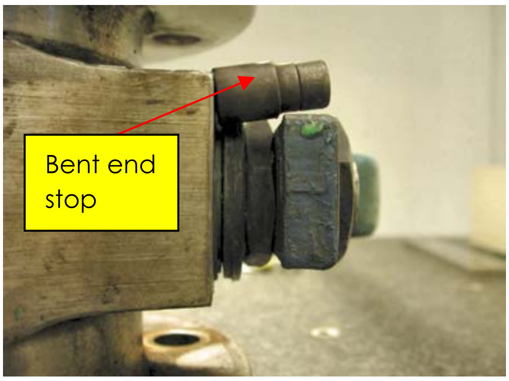


Photograph 2: leakage at the location position as
of the red blind flange.

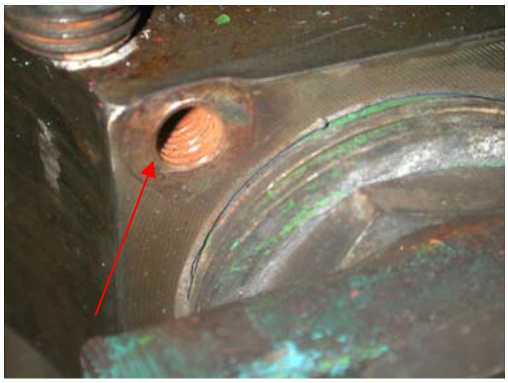


Photograph 3: handle in the

as identified in Amersfoort, due to the bent end stop.



Photograph 4: bent end stop, side view.



Photograph 5: the deformed material beneath the end stop.

1.2 Testing for leakage of the tank wagon at Kijfhoek

On 28 August 2002, the tank wagon which by this time had been cleaned, was pressurised at Kijfhoek, using compressed air, and tested for leaks. During this examination, the ball valve and the red blind flange were tested with a new gasket. The red blind flange is viewed as the **real shutoff for the riser pipe**, because there are also wagons that travel without a ball valve. In practice, overpressure can occur due to the heating of the cargo or a chemical reaction.

1.3 The following tests were carried out

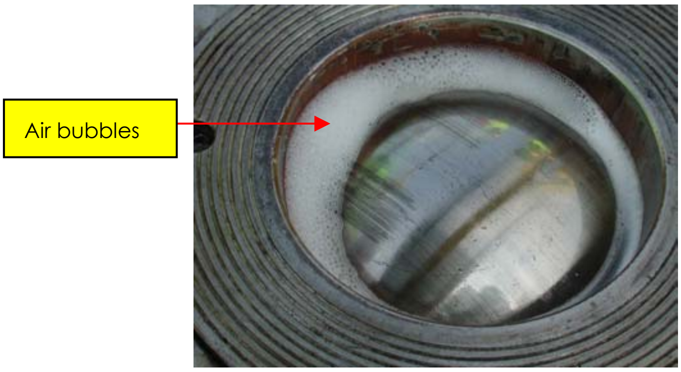
Measurement 1, tank pressure 0.3 bar, ball valve of the riser tube closed (handle horizontal), red blind flange removed, and using a soapy solution, the ball of the shutoff valve checked for leaks.

Measurement 2, tank pressure 0.3 bar, handle of the ball valve on the riser pipe as found in Amersfoort, against the bent end stop, red blind flange removed and using a soapy solution, the ball of the shutoff valve checked for leaks.

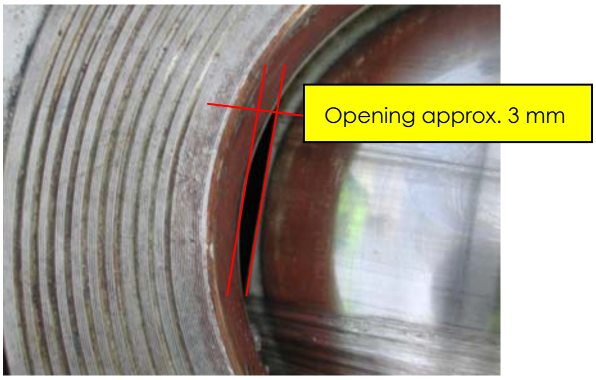
Measurement 3, tank pressure 0.3 bar, the ball valve open, the red blind flange fitted with a new gasket, using a soapy solution checked for leaks.

1.4 Results of the tests

With measurement 1, using a soapy solution, it was determined that the ball valve in the closed position (handle horizontal) leaked at an overpressure of 0.3 bar. See photograph 6.



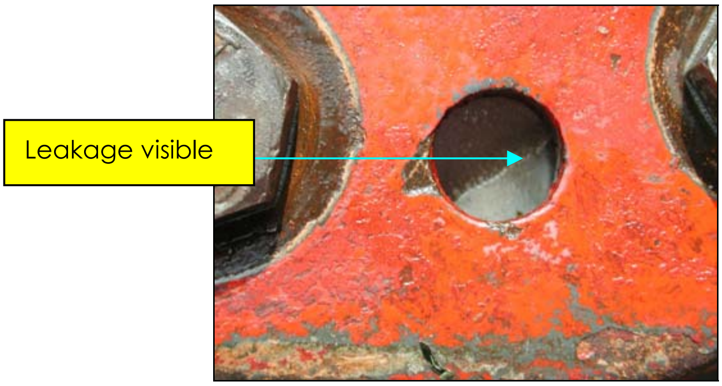
Photograph 6: leakage of the ball valve visible with soapy solution.



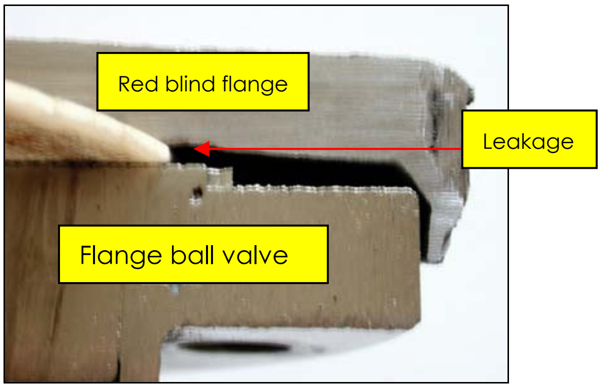
Photograph 7: ball which in the handle position does not shut off the opening.

With measurement 2, it was determined that the ball valve with the handle in the position as found in Amersfoort (against the bent end stop) leaked very severely because in this position, the ball does not shut off the opening, a gap of approx. 3 mm was still visible. See photograph 7.

With measurement 3, with the ball valve open and the red blind flange fitted, it was determined that the red blind flange leaked. Using a soapy solution, it was not possible to determine that a leak occurred. This is because the blind flange is fitted (for safety reasons) with a welded protruding edge, so that it was not possible to look directly between the two flanges, see photograph 9. In addition, the soapy solution did not reach the correct point.
By listening close to the blind flange, it was possible to determine that leakage did occur.
Only once the pressure in the tank wagon was raised to approx. 1.5 bar could it be determined using a soapy solution, with considerable effort, that leakage occurred.



Photograph 8: leakage was visible in the open hole in the blind flange.



Photograph 9: cross-section of the red blind flange and the ball valve flange.

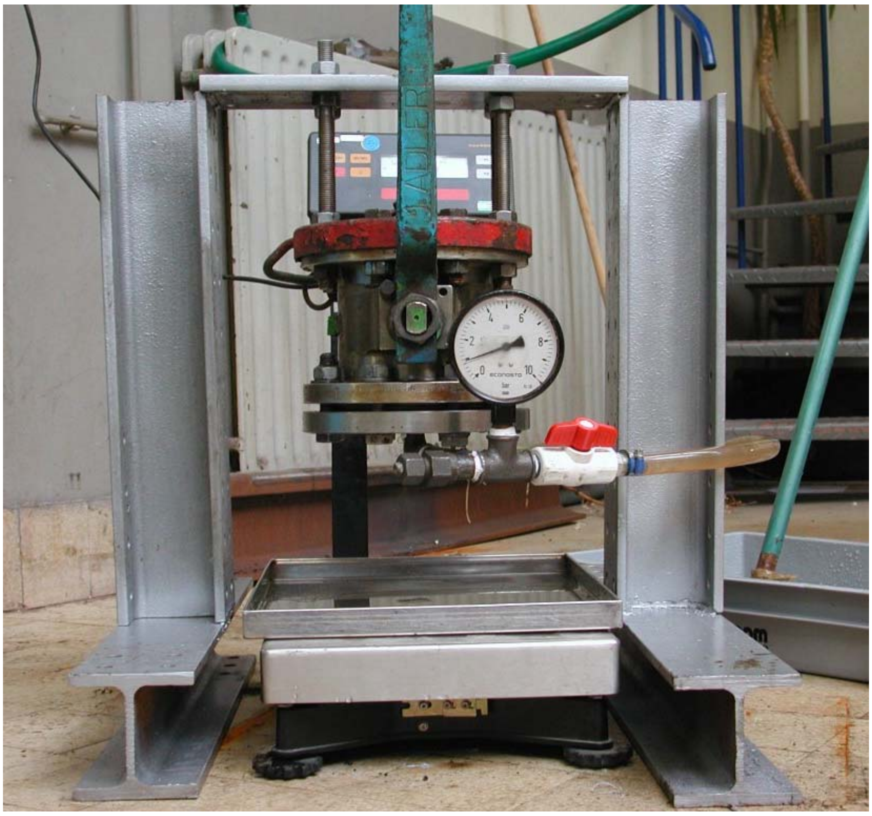
2 Purpose of the investigation

The purpose of the investigation was to determine for ourselves the cause of both the leakage between the flange on the ball valve and the blind flange, and the leakage of the ball valve itself.

3 Investigation

3.1 Determination of leakage between the flange on the ball valve and the blind flange

To be able to determine the leakage between the flange on the ball valve and the blind flange, a test bench was made.
The valve was sealed at the underside with a blind flange in stainless steel. A connection was made in this blind flange, to be able to fill the valve with water, under pressure.
The valve was closed at the top with the red blind flange with the gasket used in Amersfoort. The bolts were tightened crosswise to 120 Nm. The valve was then suspended in a frame, so that the valve was suspended practically freely.
Beneath the valve, a catch tray was placed on a set of scales, so that any leakage could be caught in the tray, and weighed. See photograph 10.
The test was carried out with the valve handle in the vertical position (open) with a water pressure of 1 bar. The measured water leakage at 1 bar overpressure was 40 g per minute, i.e. 2400 g or 2.4 litres per hour. This is the leakage under the most favourable circumstances. It may be assumed that the leakage in practice was greater.



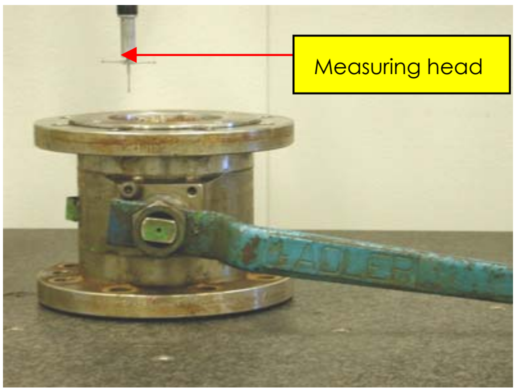
Photograph 10: Test bench for determining leakage between the flange on the ball valve and the blind flange.

3.2 Measuring parallelism and dimensioning of the flange on the ball valve and the blind flange

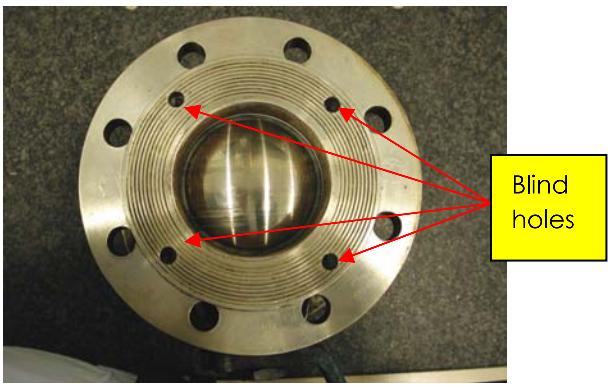
To be able to determine whether the flange on the ball valve and the blind flange are flat, both parts were measured on a 3D measuring bench, see photograph 11.

3.2.1 Flange on the ball valve

The flange on the ball valve was measured across the width of the gasket face, at various positions around its circumference.
There are 4 blind holes in the gasket face of the flange, see photograph 12.
On the drawings, see appendix 1, of the ball valve as received from VTG, no blind holes are shown in the gasket face.



Photograph 11: valve on the 3D bench.



Photograph 12: top view of flange with 4 blind holes.

The flange was correctly flat, with a maximum deviation across all measuring points of 0.06 mm.
It was determined that the gasket face of the flange was slightly angled outwards to inwards, by approx. 0.03 mm, see figures 2 and 3. All other measurement sheets have been enclosed as appendix 2.

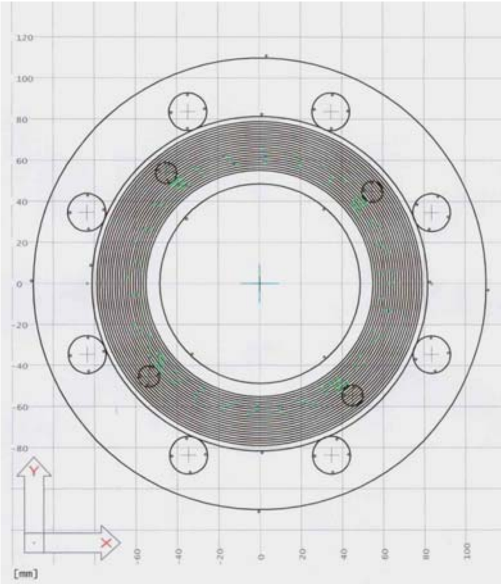


Figure 2: measurement sheet for the flange of the ball valve.

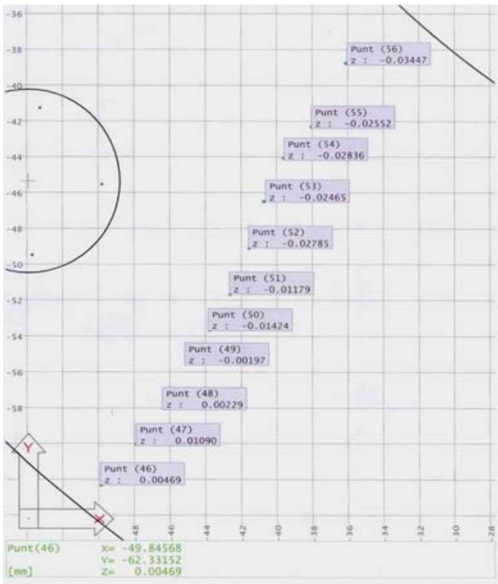


Figure 3: detail of measurement sheet, measurement across the width of the gasket face.

3.2.2 Blind flange

The blind flange was also measured on the 3D bench, at 53 points on the gasket face. The maximum deviation was 1.6 mm, see figure 4. All measurement sheets have been enclosed as appendix 2.

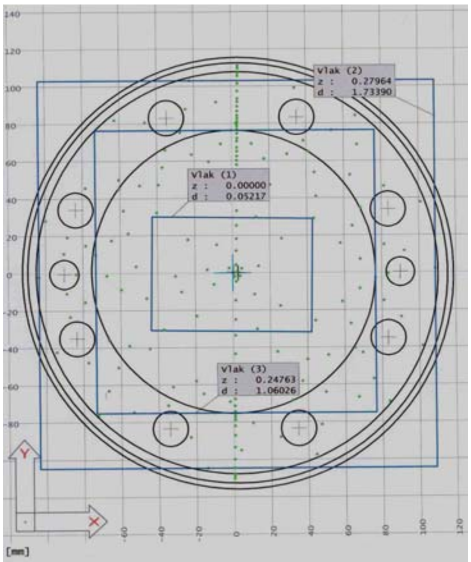


Figure 4: measurement sheet of blind flange.

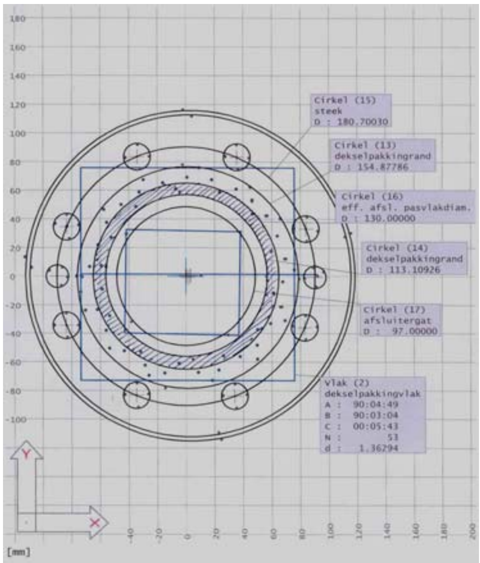


Figure 5: hatched area is effective gasket face.

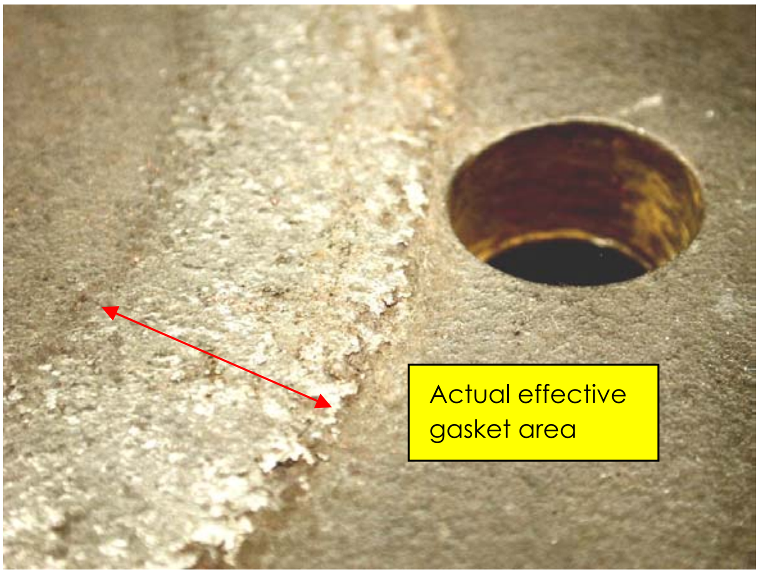
3.3 Surface quality of the flange on the ball valve and the blind cover

3.3.1 Flange on the ball valve

The surface quality of the flange on the ball cock was measured with a roughness meter. Although difficult to measure due to the grooves ground into the flange on the ball valve, see photograph 12, the Ra value was at a normal level.

3.3.2 Blind flange

The surface quality of the blind flange was so poor, due to the occurrence of corrosion, that it could not be reliably measured using the sensitive roughness measuring equipment (beyond the measuring range).



Photograph 13: actual effective gasket area.

The total surface on the inside of the blind flange was rusted, and on the gasket face itself there was a relatively thick layer of rust and old gasket material.

The gasket face is higher than the rest of the blind cover, see photograph 13. The blind holes on the flange on the valve are just beyond this raised gasket face on the blind flange.
As a consequence, only a small part of the gasket face of the blind flange is actually effective; see the hatched ring on figure 5.

3.4 Microscopic investigation of the surface of the flange on the ball valve and the blind flange

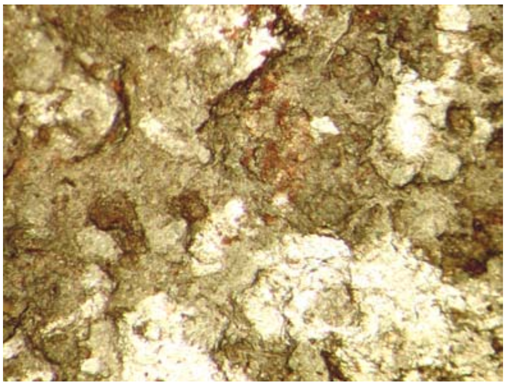
3.4.1 Flange on the ball valve

During microscopic investigation of the flange on the ball valve, beyond a number of minor damaged points, no deviations were found.

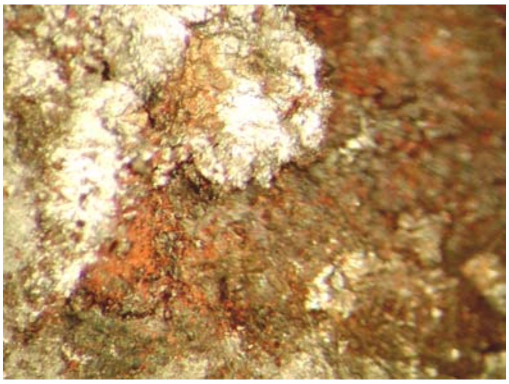
3.4.2 Blind flange

The surface quality of the blind flange was examined microscopically, see photographs 14 to 17, which were made with different magnifications. Photograph 17 is a view slightly at an angle to the surface, clearly showing that the layer on the gasket face of the blind flange is porous.

Photograph 14: magnification 10x.



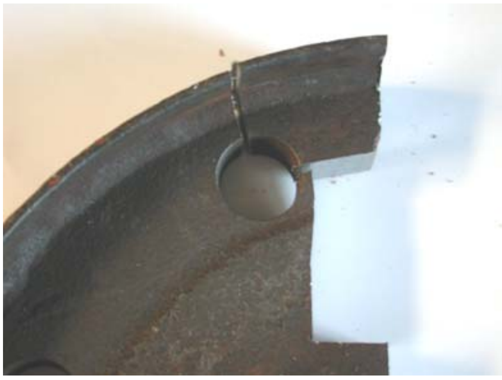
Photograph 15: magnification 20x.



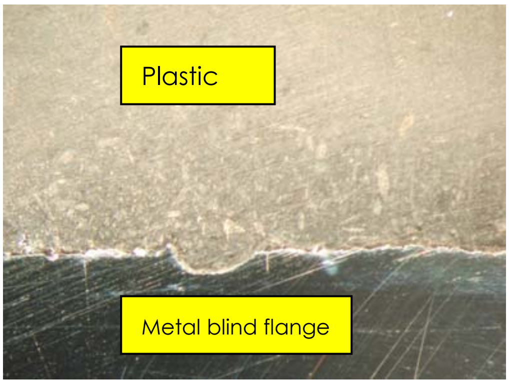
Photograph 16: magnification 40x.

Photograph 17: magnification 40x.

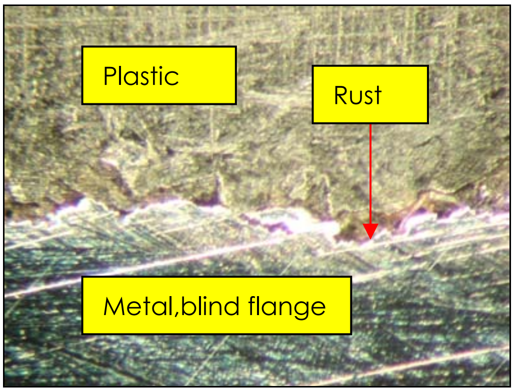
The blind flange was sawn through and at the saw cut, a preparation was removed, in order to show the rust layer. See photograph 18.
The material removed was embedded in plastic, ground and polished, so that the cross-section could be examined under the microscope, see photographs 19, 20 and 21.



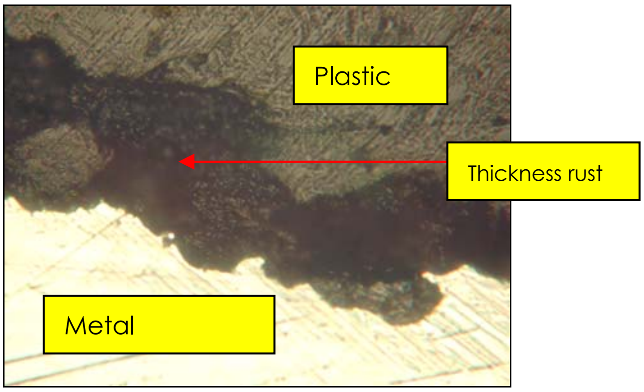
Photograph 18: section removed for microscopic investigation.



Photograph 19: magnification 20X.



Photograph 20: magnification 40X.



Photograph 21: magnification 200X.

3.5 Chemical analysis of the layer present on the gasket face of the blind cover

The layer on the gasket face of the blind flange was examined using instrumental analysis techniques, X-ray fluorescence and infrared spectrometry.
The majority of the layer consisted of iron corrosion.

3.6 Investigation of the gasket, material composition, compatibility dimensioning and surface quality

3.6.1 Material composition

Using infrared spectrometry, the gasket material was examined, see the infrared spectrum in figure 6. The red line in the spectrum shows the gasket material, the black line is a reference sample of Teflon. The peaks in the wave length area around 1250 cm-1 show that the gasket material is Teflon.

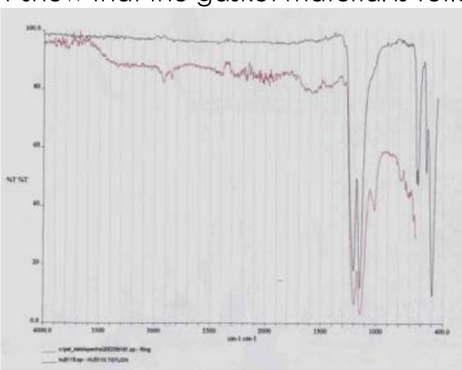


Figure 6: infrared spectrum of gasket material.

3.6.2 Compatibility of the gasket material

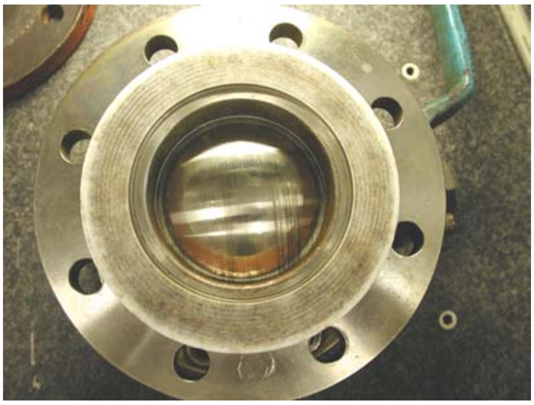
Teflon is resistant to acrylic nitrile, and is therefore suitable as a gasket for this application.

3.6.3 Surface quality and dimensioning of the gasket

The surface appears normal, with some iron corrosion particles embedded locally. The material shows plastic deformation; the impression of the grooves on the flange of the ball valve is visible, see photograph 22. The impression of the grooves on the outside diameter is deeper than on the inside diameter, which indicates that the pressure on the gasket was higher, on the outside edge.

The dimensioning of the gasket is not ideal. The external diameter of the gasket is in fact slightly too large, as a result of which it was difficult to insert the bolts through the holes in the flange, see photograph 23.
The internal diameter is too large; the internal diameter of the gasket should be the same as the internal bore of the ball valve flange; the result is a greater gasket area.

Photograph 22: the gasket used in Amersfoort.



Photograph 23: gasket on the valve.

3.7 Turnability of bolts used

The bolts turn smoothly, but it is notable that various bolt types were used. The differences are in material quality, see photograph 24. In this application, the difference in material quality plays no role. The quality indication appears below the bolts. Carbon steel bolts were used, both zinc galvanised and non-zinc galvanised, and stainless steel bolts were also used.

5.8	5.8	5.8	5.8	8.8	8.8	A2	A4 8.0

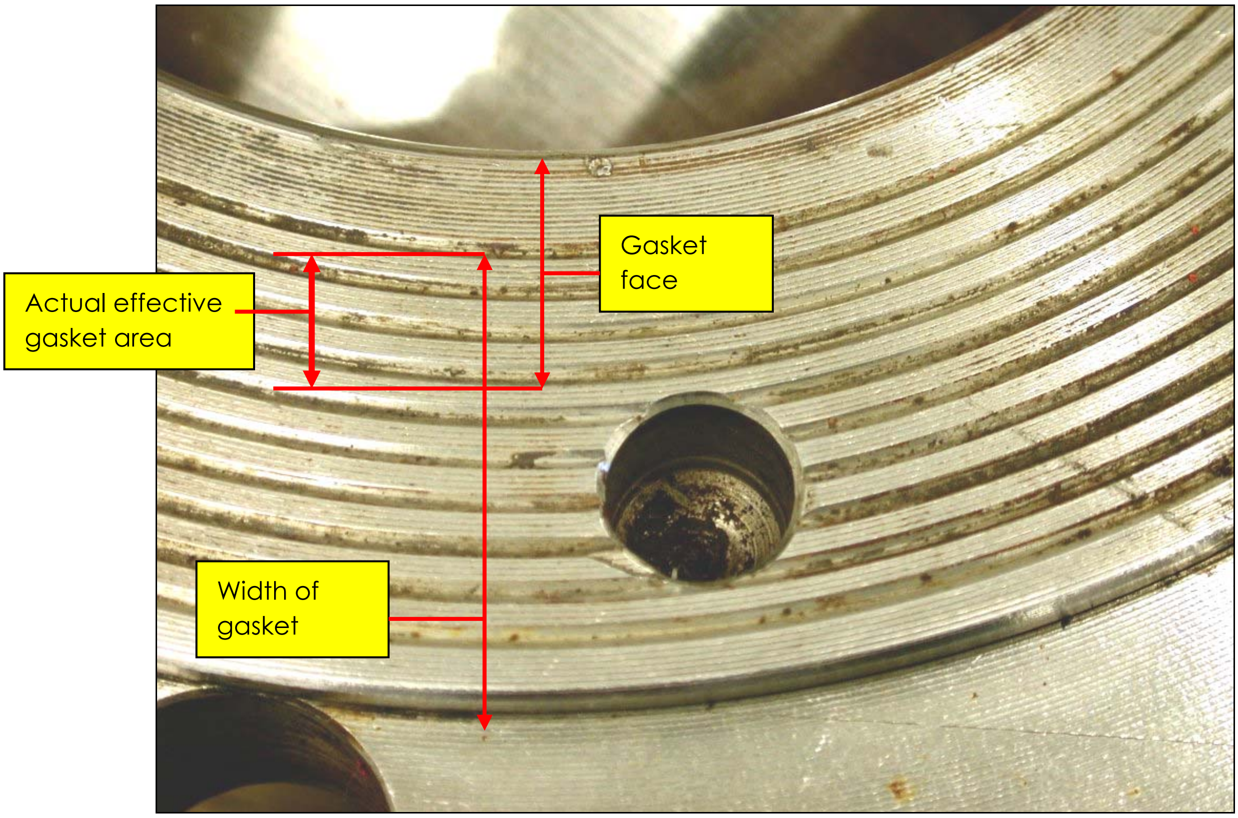
Photograph 24: various material qualities of the bolts used.

3.8 Assessment according to specifications/drawings

On the drawings received from both the rolling stock owner and from the supplier of the ball valve, the blind holes discovered in the ball valve flange are not shown. See appendix 1.

These blind holes reduce the actual effective gasket area by approx. 70%.

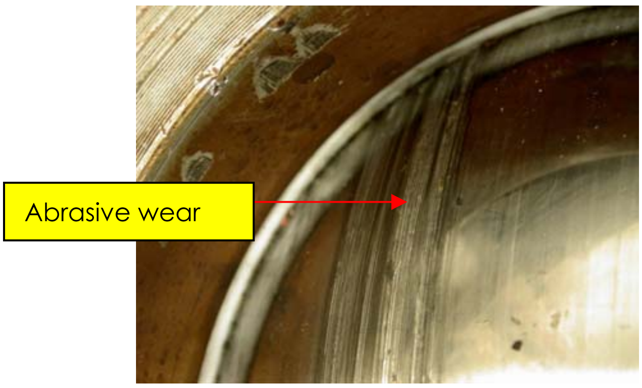
Due to the corrosion which occurred, the blind flange has only a relatively small remaining gasket area, see photograph 13. Due to the blind holes in the flange on the ball valve and the not perfect fitting of the gasket, only a small actual effective gasket area remains, see photograph 25.



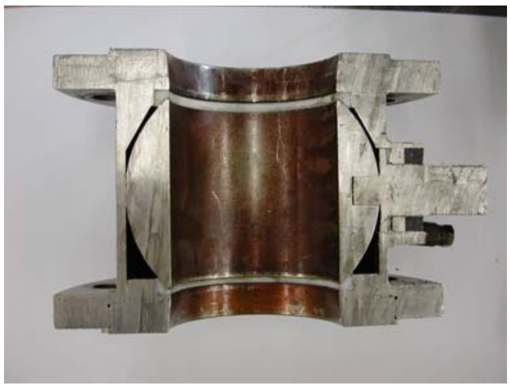
Photograph 25: actual effective gasket area.

3.9 Cause of the leakage of the ball valve

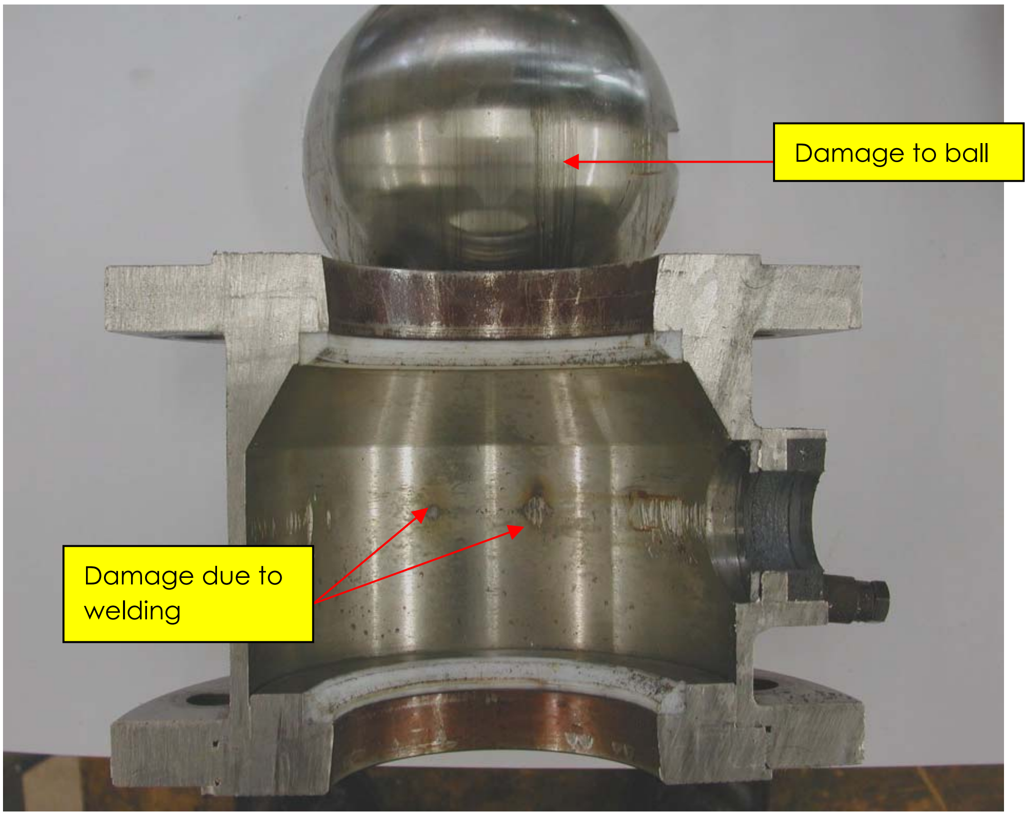
The cause of the non-sealing of the ball valve itself is easily visibly observable, with the handle in the horizontal position. The ball of the valve is damaged due to abrasive wear, see photograph 26. This form of wear is caused by hard particles. To determine the origin of these particles, the ball valve was sawn through, see photograph 27.



Photograph 26: abrasive wear of the ball.

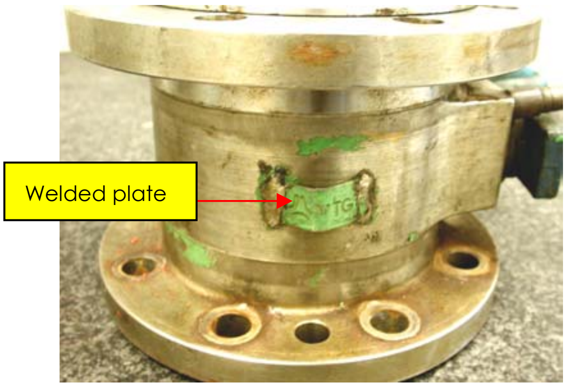


Photograph 27: cross-section of ball valve.

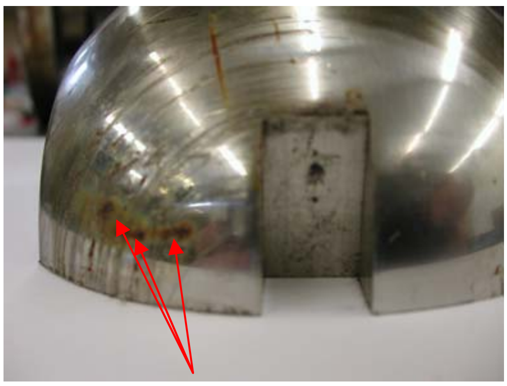


Photograph 28: damage to the valve housing due to the welding on of a manufacturer's plate. The position precisely matches the damage to the ball.

Once the ball had been sawn through, damage was found in the ball valve housing, at the precise location of the damage to the ball, see photograph 28.
This damage to the housing of the ball valve was caused by the welding of a name plate onto the valve, see photograph 29. More burn-in points and abrasive wear points were found on the ball, see photograph 30. All this points towards the fact that during welding, the earthing terminal was placed on the handle, as a result of which spark-over occurred via the ball to the valve housing, leading to the ball becoming welded tight. Once these micro-welds broke free, rough, hard points occurred, which caused the wear identified.



Photograph 29: name plate welded onto the valve.



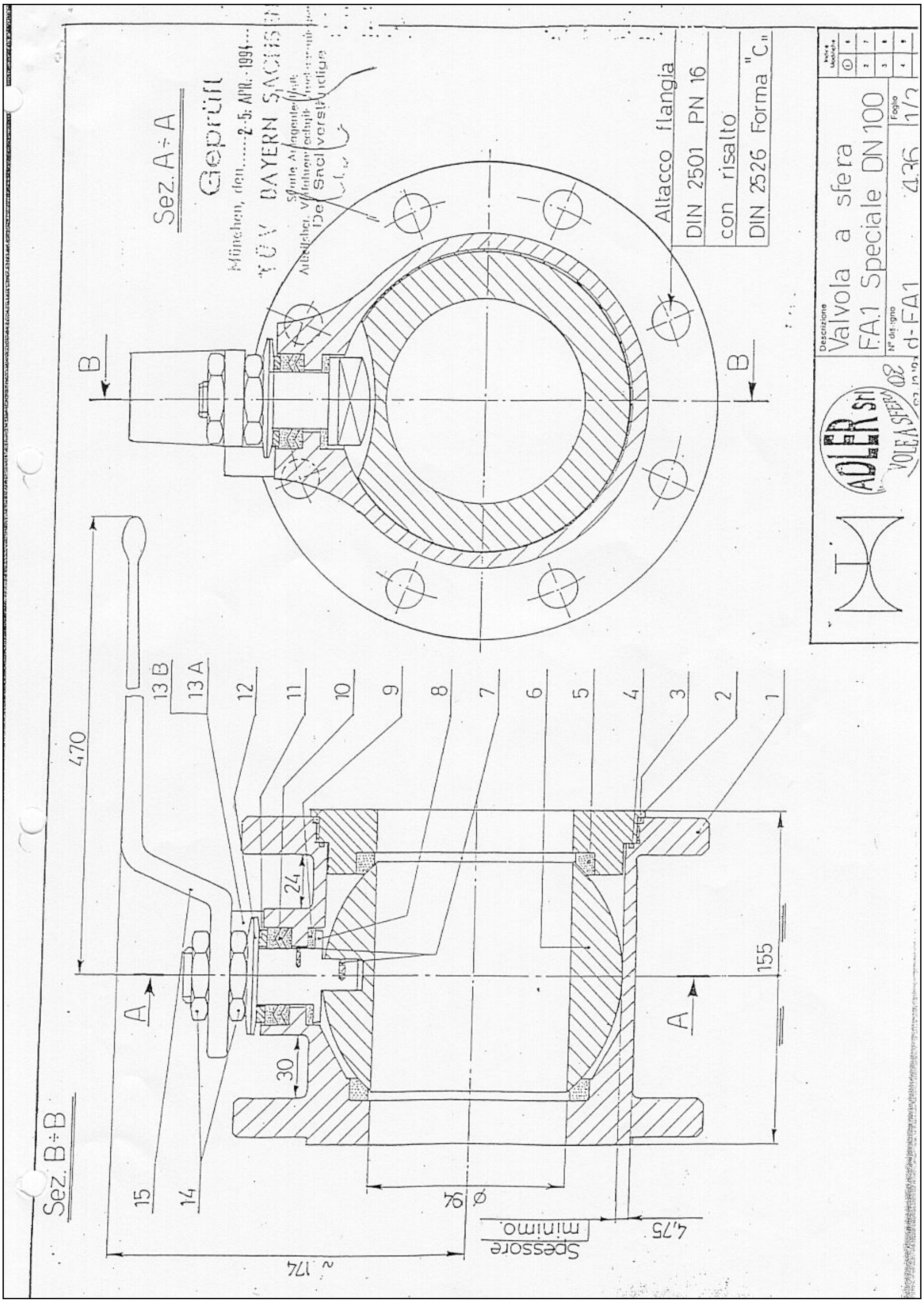
Photograph 30: more burn-in points on the ball.

4 Conclusion

- The cause of the leakage was the poor condition of the blind flange, with the highly corroded surface, which was both porous and not flat.
- The valve was damaged and leaky due to abrasive wear caused by welding on the valve.
- The handle of the valve was turned beyond the horizontal position, because the end stop had been bent by force.
- The effective gasket face was far smaller than intended due to the blind holes and the poor condition of the blind flange.

5 Recommendations

- In our opinion, on a stainless steel ball valve a stainless steel blind flange should be fitted, certainly if used with corrosive products of this kind. No welding should be carried out on a valve.
- A shutoff valve should be used without the blind holes found in this case. As a result, the gasket face becomes larger and the risk of leakage is considerably reduced.
- The area of the gasket should be better matched to the dimensions of the valve, for the above described reasons.
- In our opinion, the checking of the shutoff devices as specified in the VSG/ RID 1.4.3.3 f, at the premises of the forwarder, is not or barely possible. We recommend that you investigate how these actions are currently carried out. A reliable measurement such as the measuring method using the soapy solution should be used, in our opinion. All the more because we expect that the situation with the two other blue blind flanges (gaseous phase) is not much better.
- A good inspection protocol for the ball valve should be introduced. Both of the defects discovered were clearly visually observable.


Sez. A÷A
Geprüft
Sez. B÷B
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DIN 2501 PN 16
con risalto
DIN 2526 Forma "C"
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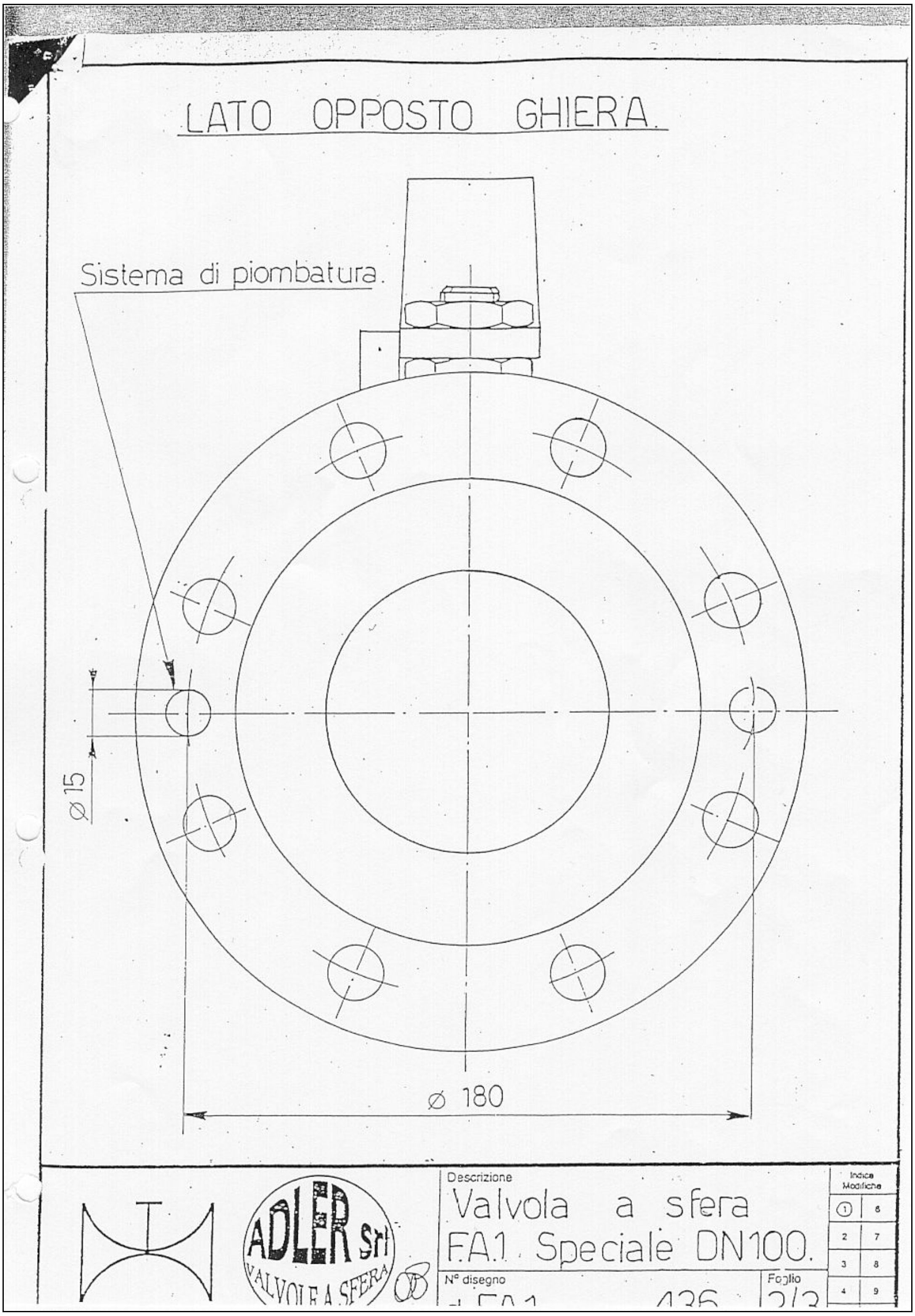
LATO OPPOSTO GHIERA.
Sistema di piombatura.
ø 15
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ADLER srl
VALVOLE A SFERA
Descrizione
Valvola a sfera
F.A.1 Speciale DN100.
N° disegno
Foglio
Indice Modifiche
1
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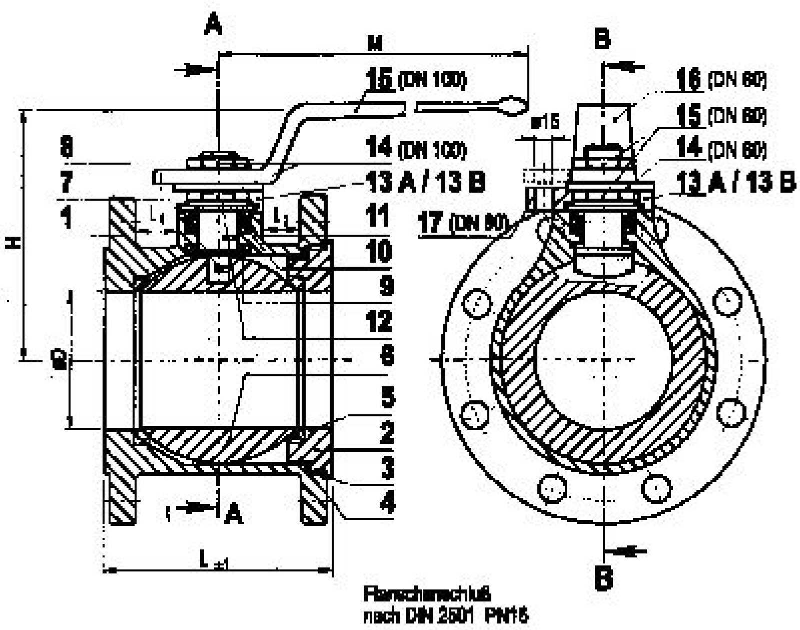
VTG	Kompakt-Flanschkugelhahn DN 80 und DN 100 Adler / Euromatic	ZV 57.2



Schnitt B - B

Schnitt A - A

ZV 57.2 Adler Kompakt-Kugelhahn
Typ EA 1, Spezialausführung

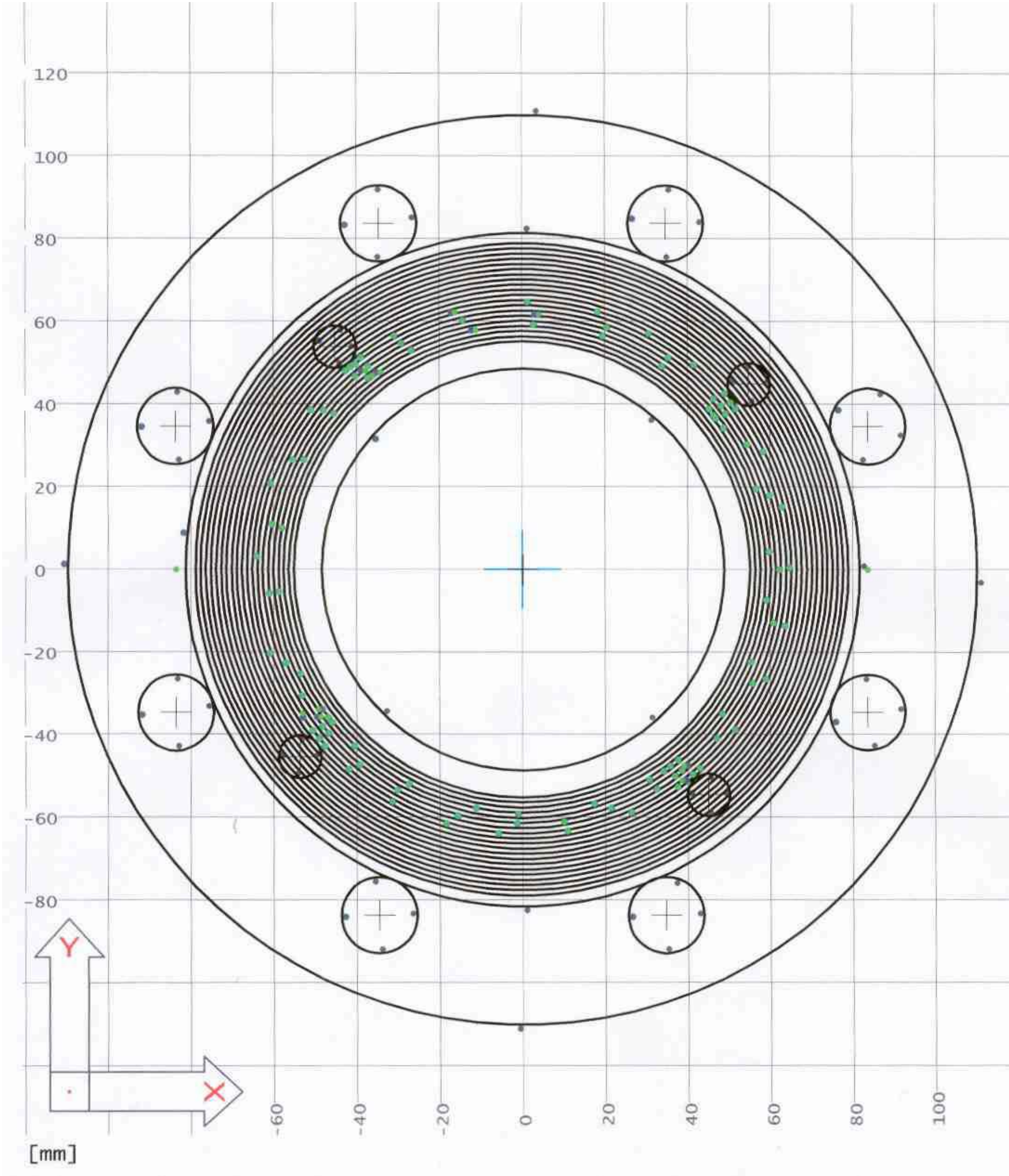
ZV057.2	100	94	156	30	24	174	470	ø220/ø180 (n. DIN 2501 PN16)	21,0
ZV057.2	80	78	130	19	29	153	370	ø200/ø160 (n. DIN 2501 PN16)	16,0
Ventil-	DN	ØD	L	L_1	L_2	H	M		kg
bezeichnung	Größe	Baumaße						Anschlußflansch	Gewicht

KS-MBA 57-251A Ausgabe: 12.2000 Seite 3

VTG	Kompakt-Flanschkugelhahn DN 100 Adler / Euromatic	ZV 57.2

Ersatzteilliste ZV 57.2 - DN 100

15	Handhebel		1	M-F-C-16-100		
14	Kontermutter		2	D-F-Z-16-100	UNI 3740 6S Zn	
13B	Anschlag,Distanzstück		1	DF-F-Z-16-100	9S Mn Pb 23 UNI5105	
13A	Anschlag, Schraube		2	VF-F-Z-16-100	UNI 3740 8.8 Zn	
12	Tellerfeder		2	MT-F-Z-16-100	C 72 Zn	
11	Stopfbuchsdruckring		1	P-F-F-16-100	ASTM A182 F 316 L	
10	Dachmanschette		1	PV-F-TG-100	PTFE/Graphit	
9	Schaltwellendichtung		1	B-F-TF-16-100	PTFE	
8	Schaltwelle		1	ST-F-F-16-100	ASTM A 182 F 316	
7	Antistatik-Vorrichtung		1	DA-F-F-16-100	ASTM A 182 F 316	
6	Kugel		1	S-F-D-F-16-100	ASTM A 182 F 316	
5	Sitzdichtung		2	SB-F-TF-16-100	PTFE	
4	Dichtungsring		1	A-F-TF-16-100	PTFE	
3	O-Ring		1	OR-F-VT-16-100	Viton	
2	Gewindedruckring		1	GA-F-16-100	ASTM A 182 F 316	
1	Gehäuse		1	C-FAS-F-16-100	ASTM A 182 F 316	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100
80
60
40
20
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-20
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-60
-80
Y
X
-60
-40
-20
0
20
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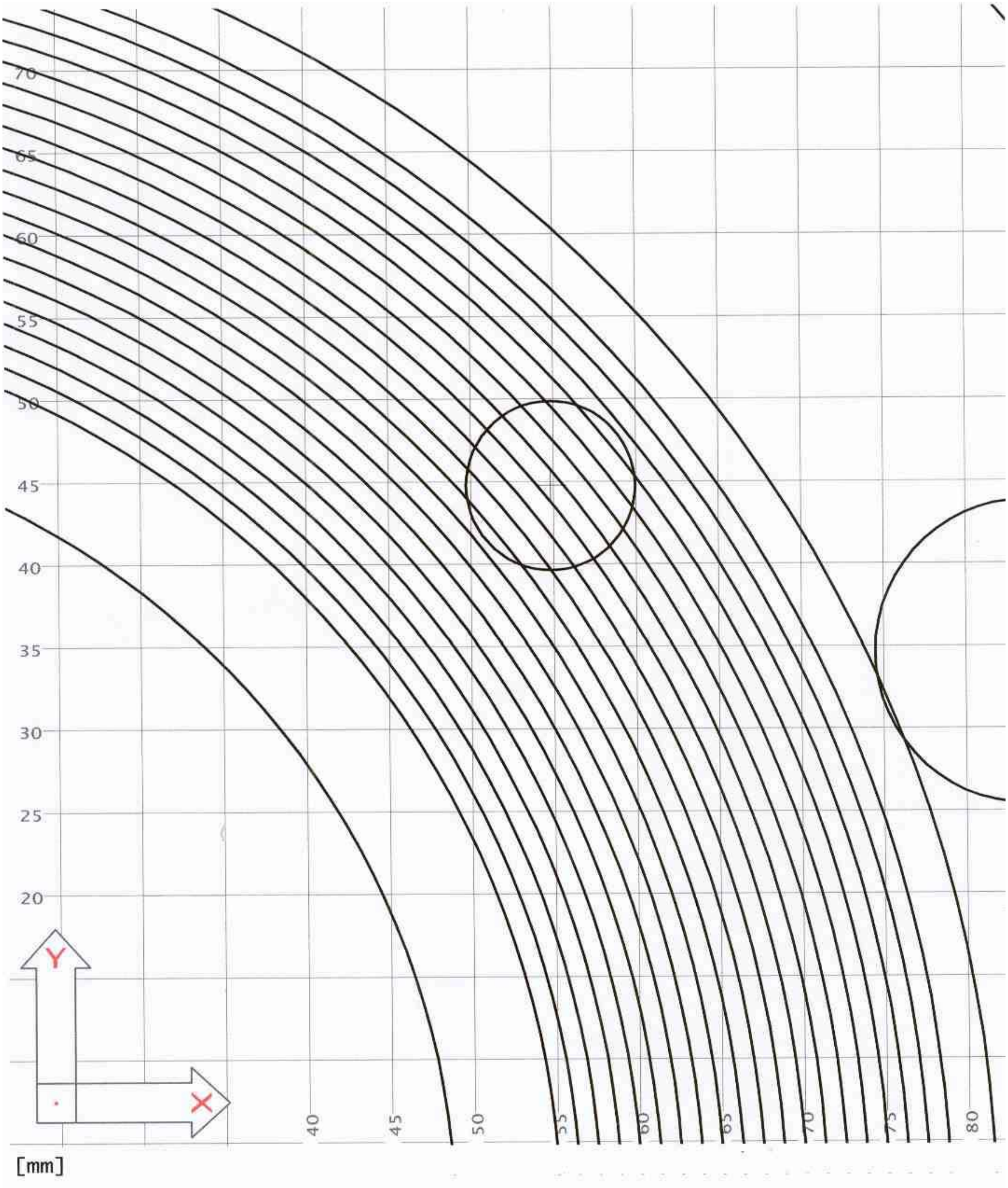
60
80
100
[mm]


70
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X
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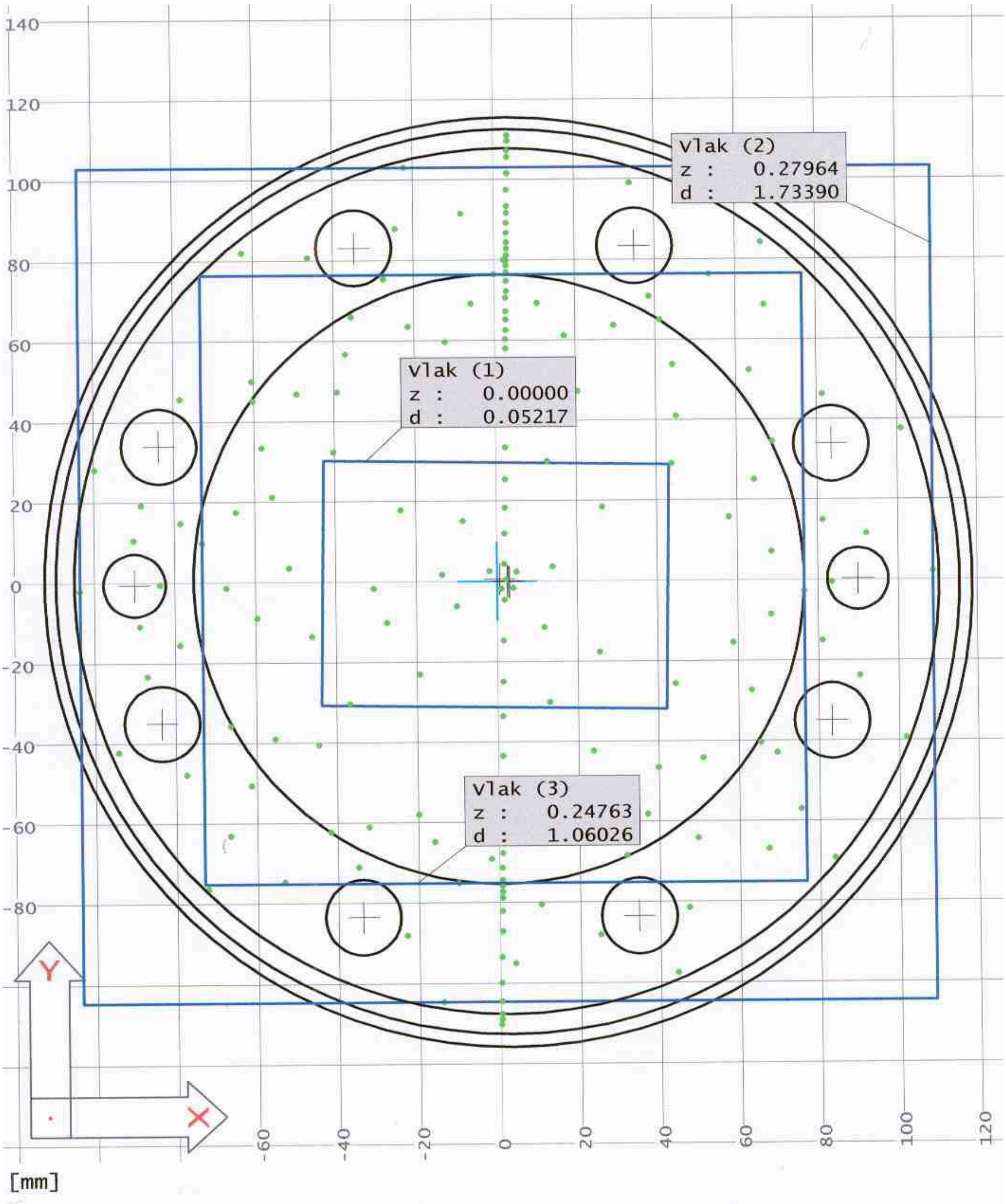
70
75
80
[mm]


Vlak (1)
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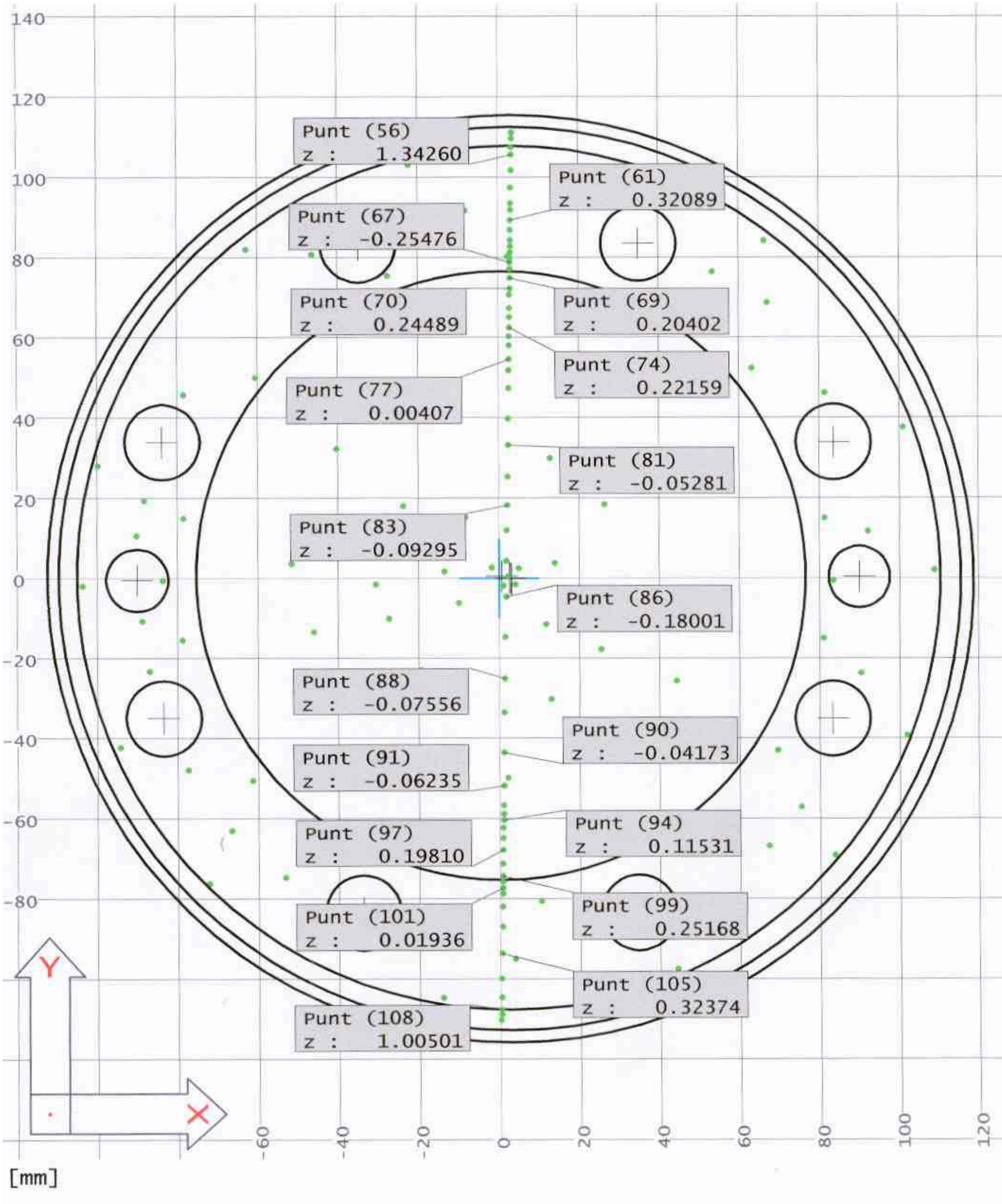
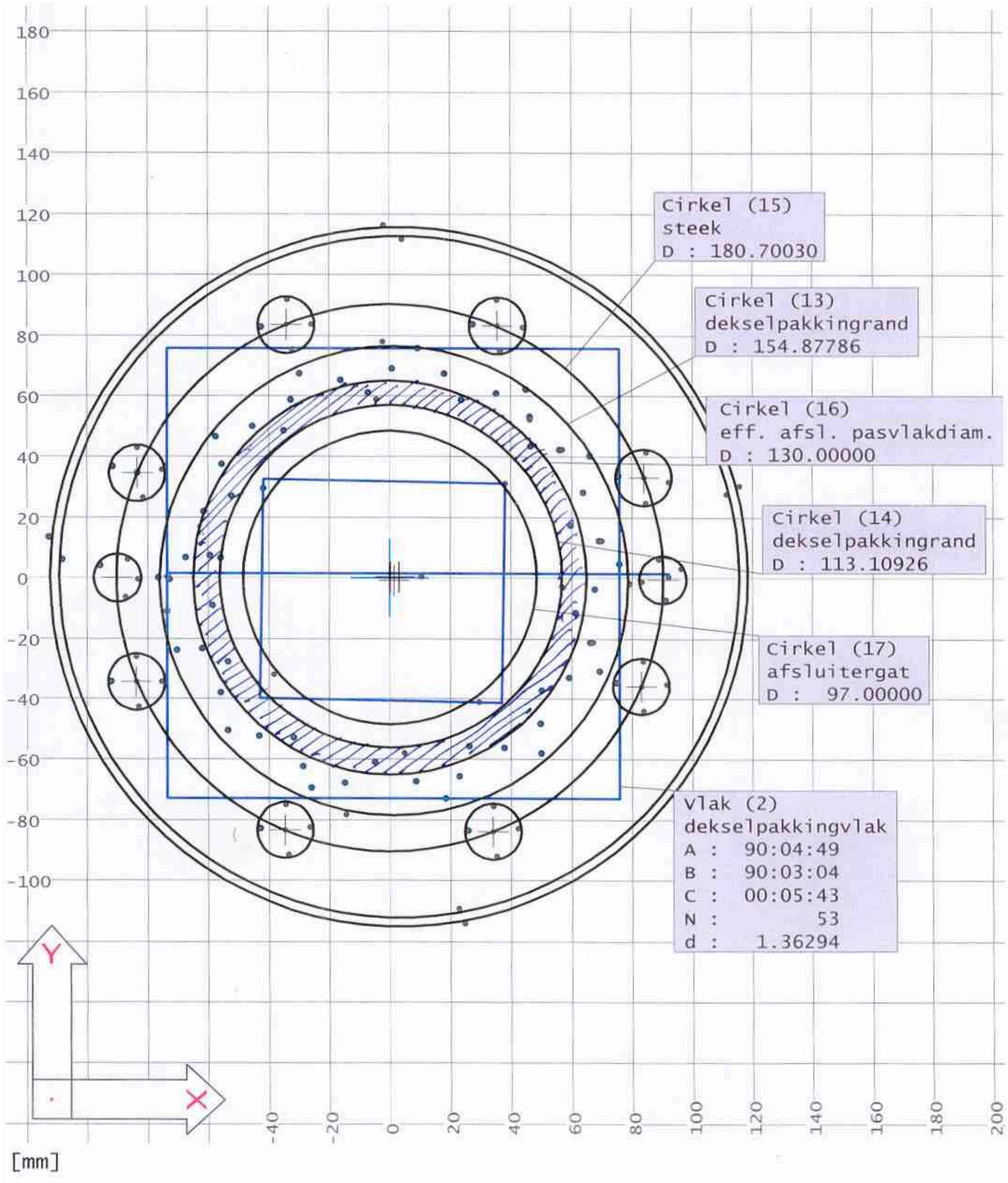
d : 0.05217
Vlak (2)
z : 0.27964
d : 1.73390
Vlak (3)
z : 0.24763
d : 1.06026
Y
X
[mm]



140
120
100
80
60
40
20
0
-20
-40
-60
-80
Punt (56)
z : 1.34260
Punt (61)
z : 0.32089
Punt (67)
z : -0.25476
Punt (70)
z : 0.24489
Punt (69)
z : 0.20402
Punt (74)
z : 0.22159
Punt (77)
z : 0.00407
Punt (81)
z : -0.05281
Punt (83)
z : -0.09295
Punt (86)
z : -0.18001
Punt (88)
z : -0.07556
Punt (90)
z : -0.04173
Punt (91)
z : -0.06235
Punt (94)
z : 0.11531
Punt (97)
z : 0.19810
Punt (101)
z : 0.01936
Punt (99)
z : 0.25168
Punt (105)
z : 0.32374
Punt (108)
z : 1.00501
Y
X
-60
-40
-20
0
20
40
60
80
100
120
[mm]


Cirkel (15)
steek
D : 180.70030
Cirkel (13)
dekselpakkingrand
D : 154.87786
Cirkel (16)
eff. afsl. pasvlakdiam.
D : 130.00000
Cirkel (14)
dekselpakkingrand
D : 113.10926
Cirkel (17)
afsluitergat
D : 97.00000
Vlak (2)
dekselpakkingvlak
A : 90:04:49
B : 90:03:04
C : 00:05:43
N : 53
d : 1.36294
Y
X
[mm]