TROMBIK ENGINEERS Ltd.
Dipl. Ing. ETH/SIA/USIC
Limmattalstrasse 344
CH - 8049 Zürich

Tel: +41 (0)44 344 41 71
Fax: +41 (0)44 344 41 72
Email: trombik@trombik.ch
Web: www.trombik.ch

Spring Mounted Machine Foundations

Revision Works / Inspections, Operational Reliability

Spring Elements, Belleville Washers, R.C. Foundation

Memorandum N°: 999.10.001.0

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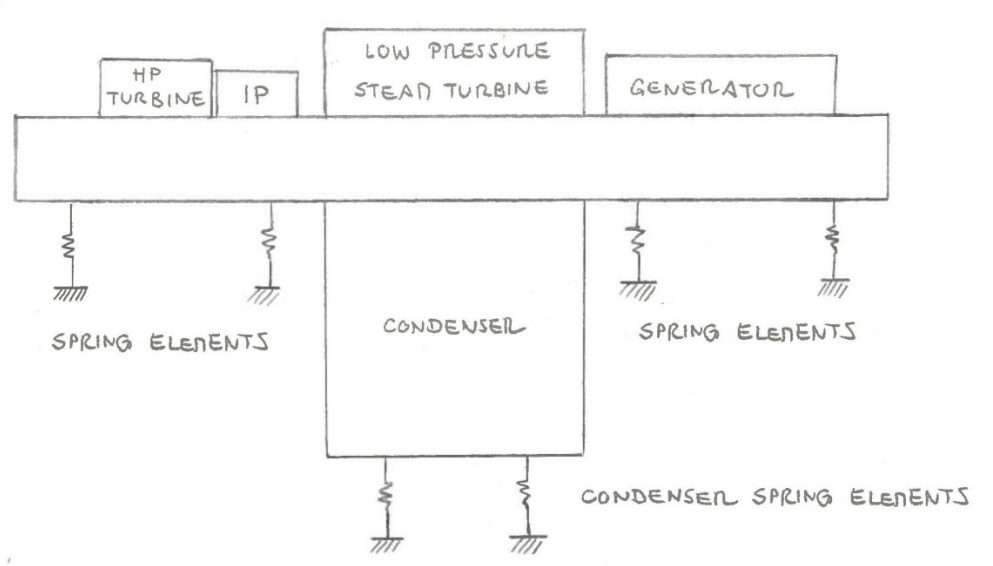
1. INTRODUCTION

1.1. MOTIVATION

Spring mounted machine foundations are structures designed for a lifetime period; although regular checks and periodical maintenance works are recommended for the reinforced concrete and for the spring elements to guarantee a correct operation of the decoupled foundation system.

Trombik Spring Elements are high quality products, insensitive against external influences; in order to guarantee their correct functionality, periodical revision and maintenance work are recommended. By checking and overhauling the functionality, e.g. the vibration-isolation between the machine foundation and the substructure can be guaranteed.



Sketch of the longitudinal section of a classical Spring Mounted Machine Foundation

Further on, over the years effects like creeping and shrinking of the reinforced concrete foundation lead to normal long-time deformations, which can affect the machine operation (misalignment of the machine shaft line).

This memorandum summarises usual revision works, inspections and toptable adjustments for spring mounted machine foundations.

2. REVISION WORKS

2.1. REVISION WORK ON SPRING ELEMENTS

It is recommended to perform small revision works every 5 to 10 years (visual inspections, pressure checks) and complete revision works every 20 to 30 years (complete disassembly of all movable parts).

- Most important of course are **the Belleville Washers**: unusual impacts (accidental loading situations / overloads, corrosive substances, etc.) to the spring elements may lead to small cracks or/and to fractions in Belleville washer. Generally, cracks can be detected by eye; no special equipment has to be on site. Dye penetrant (e.g. MPI), X-ray or loading test are possible. Based on experience with similar investigations it can be assumed that after a period of 25 years a number of about 2÷5% of all Belleville Washers has to be replaced.

- **Casing**: visual inspections, sometime rust on the surface and partly peeling of the colour layer → new paint finish.

- Other **secondary parts** (as Teflon lining, Bituminous felt pads, Quick couplers if applicable) are replaced where needed.

2.2. IDENTIFICATION OF THE OPERATIONAL RELIABILITY

N°	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**
Description	**New Spring Elements (redesigned)**	**Replacement of all Bellville Washers**	**Overhaul of all Bellville Washers at manufactures place**	**Overhaul of all Bellville Washers on Site**	**Visual Inspection of all Bellville Washers on Site**	**Detailed Pressure Check of the Spring Elements**
Test			- Magnetic Particle Inspection - X-Ray - load curve	- Fluorescent Particle Inspection (Magnetic Particle Inspection) - X-Ray	Visual Inspection	Determination of the effective Spring Stiffness

Time Frame			Per outage only a part of the springs can be revised → years	Per outage only a part of the springs can be revised → years		
Costs	high / +++	++	+	0	-	low / ---
Addi-tional Tools on Site	none	none	none	- Special trained staff - MPI / X-Ray acces-sories and equipment	none	Spring Gap Gauger
Risks	Delivery / production time	Delivery / production time	Spare Belleville washers required	Spare Belleville washers required	Spare Belleville washers required	

Overhaul experiences in power plants have proven that a **Visual Inspection of all Bellville Washers on Site** (Operational Reliability N° 5) guarantees a complete, cost-efficient and reliable procedure.

All revision works have to be carried out during a shutdown of the machine (Outage or Refurbishment periods). During revision works **the deflection of the foundation is monitored by dial gauges** which have to be installed on the columns. After the revision works the hydraulic pressures might be slightly adjusted in order to return to the original foundation's height (with INTEGRAL Spring Elements only; indicative tolerance 0.05-0.10mm).

2.3. DISC SPRINGS

2.3.1 Specifications

Belleville Springs are designed to DIN 2092 and manufactured to DIN 2093, designed for critical loading or dynamic applications.

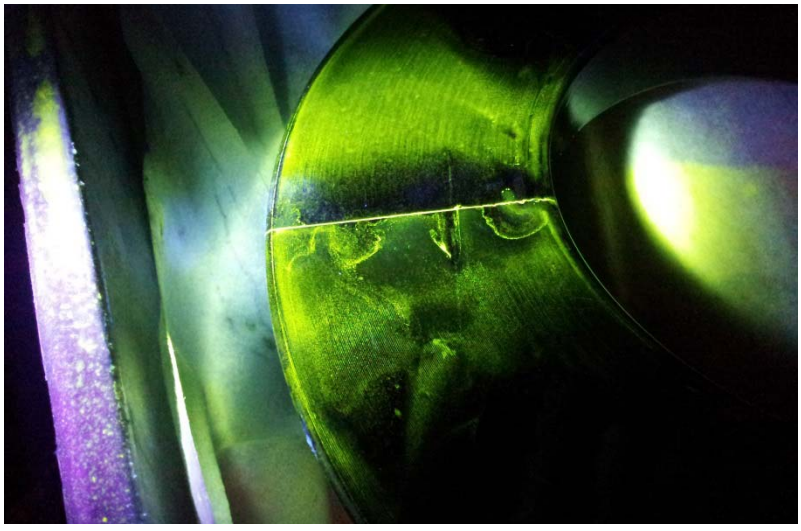
- Spring Steel: 50 CrV4 (1.8159)
- Protective / surface treatments: Phosphating (zinc phosphate and oil). This is the standard surface treatment, this finish is usually sufficient to prevent corrosion in unexposed applications and during transportation and storage.

2.3.2 Non-destructive Testing

	X-Ray Test	Ultrasonic testing	Cracks check
Recognizable defects	Internal pores, blowholes, slag inclusion, coarse cracks and bind defects, superficial defects	Possible even with large wall thickness; internal pores, blowholes, slag inclusion, fine internal cracks and bind defects	Superficial pores and cracks, included finest hairline cracks
Inspection efforts	X-ray film recording: high, but the whole workpiece is detectable; Screening: low	Low to high; Eventual scanning of the surface necessary	Low to medium; whole workpiece detectable
Equipment costs	High	medium	Low to medium

2.3.3 Fluorescent Particle Inspection (Magnetic particle testing)

Fluorescent magnetic particle inspection method is used for the detection of fine surface and slightly subsurface discontinuities in ferrous materials. Fluorescent particles are finely controlled to ensure maximum sensitivity and to encapsulate and maintain their fluorescent pigmentation for the production of superior indications and to expand bath life.



Fluorescent magnetic inspection on a cracked Belleville Washer

3. INSPECTION OF THE REINFORCED CONCRETE FOUNDATION

It is recommended to include periodical inspection work of the reinforced concrete foundation (baseplate, columns and toptable) in the maintenance plan. Regular inspections are necessary to detect if relevant cracks, concrete spalling, rusting or exposed reinforcements are present.

3.1. VISUAL INSPECTION OF EXISTING R.C. FOUNDATION TABLE

- Optical search and protocol of relevant cracks in concrete surface
- Optical Check of anchorages and embedded parts
- Optical search of other relevant irregularities, such as severe concrete spalling, rusting of exposed reinforcing, heavy oil spills, chemical contamination, etc.
- Local tests of concrete strength by “Schmidt” concrete test hammer
- Results analysis and evaluation of restoration measures, if required

3.2. ASSESSMENT OF FURTHER ON-SITE TESTS, SUCH AS POSSIBLE

- Electronic measuring of concrete cover
- Determination of carbonation and chloride content (taking of drill samples and testing in laboratory)
- Detailed strength tests (taking of drill samples and testing in laboratory)
- Etc.

4. TOP TABLE READJUSTMENT

Over the years effects like creeping and shrinking of a reinforced concrete foundation lead to normal long-time deformations of the top table, which can affect the machine operation (misalignment of the machine shaft line). By major adjustments on the spring supports based on an individual elaborated Spring-Force-Matrix, a close to the origin foundation elevation can be reached (readjusting of the deformations of the reinforced concrete foundation table, as far possible, according special calculated displacement matrix).

On site, the readjustment of the foundation table itself can be performed within 1 to 2 days. This work is normally coupled with other general work on spring elements during outages.

5. CONCLUSIONS / RECOMMENDATIONS

- Main revision works on Spring Elements (complete disassembly of all movable parts) are recommended every 20-30 years in order to guarantee i.a. the vibration-isolation between the machine foundation and the substructure. Periodical checks and when required replacement of cracked Belleville Washers ensures the correct function of the Spring Elements.
- The inspection of the reinforced concrete foundation (baseplate, columns and table) can be performed at the same time as the Spring Elements revision works.
- A top table readjustment can be carried out if relevant deformation were detected. Small misalignment of the machine shaft axis can be usually corrected by adjusting the spring elements - the readjustment of the foundation table is an efficient, quick and economically attractive option.
- The revision works on Spring Elements as well as the top table readjustment have to be carried out during a shutdown of the machine (Outage or Refurbishment) and be monitored by dial gauges.

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Daniele Cavalli
Grad. Eng. BSc
TROMBIK Engineering Ltd.

Pascal Fleischer
Grad. Eng. MSc/ETH/HTL/SIA
TROMBIK Engineering Ltd.

A. SELECTED REFERENCES OF REVISION WORKS / INSPECTIONS OF SPRING MOUNTED MACHINE FOUNDATIONS

Njimegen, Netherlands
Year of construction: 1974
Machine type: Turbo Generator
Complete revision works of the Spring Elements (2005, 2009)

Tihange 3, Belgium
Year of construction: 1976
Machine type: Turbo Generator
Complete revision works of the Spring Elements (2007, 2009, 2018)

Doel 4, Belgium
Year of construction: 1978
Machine type: Turbo Generator
Complete revision works of the Spring Elements (2007; 2017, 2018)

Darlington, Canada
Year of construction: 1980-4
Machine type: Turbo Generator (4 Units)
Complete revision works of the Spring Elements (starting 2009 – ongoing)
Readjustment of the foundation table (2009-10)

Deeside, Great Britain
Year of construction: 1993
Machine type: Turbo Generator
Complete revision works of the Spring Elements (2010)
Inspection of the reinforced concrete foundation (2010)
Readjustment of the foundation table (2010)

Oyster Creek, USA
Year of construction: 1993
Machine type: Turbo Generator
Partial readjustment of the foundation table (2014)
Complete revision works of the Spring Elements (2018)

Jorf Lasfar, Morocco
Year of construction: 1995
Machine type: Turbo Generator (2 Units)
Complete revision works of the Spring Elements (starting 2016- ongoing)
Readjustment of the foundation table (scheduled)

B. EXAMPLE OF REVISION WORKS

Trombik Engineers Ltd. developed many different types of Spring Elements, individually designed for each project (in particular bearing capacity and stiffness). For the most of the spring mounted machine foundations the installed Spring Elements are the types “PRIMO” or “INTEGRAL”.

Revision works on INTEGRAL Spring Elements. In the shown case (200t Spring Elements) special tools were developed for the displacement of the upper and lower cases; the deteriorated Vulkollan pads were removed and replaced with Bituminous felt pads.

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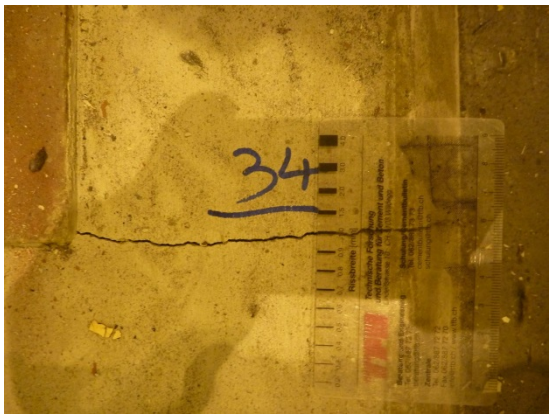
Check of the Belleville washer after dismantling the Spring Element: Cracks on discs are usually detectable by eye. A Fluorescent Particle Inspection can be taken into account for a more detailed control. After the inspection the Belleville washers are greased and reinstated inside of the washers can.

Dismantle and check of the Belleville washers inside of a PRIMO Spring Element. During the revision works the table deflection is constantly monitored with dial indicators. Temporary stops are tightened before releasing the pressure of the Spring Element; after the complete revision the spring load is set back to the initial load. An equalizing of the spring loads on a column might be carried out where necessary.

Superficial corrosion of the Belleville washer (visible next to the 'Gap' of the PRIMO Spring Element) due to a highly saline and corrosive environment: During the disassembling of the Spring Element, the discs are checked, cleaned and greased.

C. EXAMPLE OF FOUNDATION TABLE'S INSPECTION

The inspection of the foundation table consists in a visual check of the state of the supporting structure (base plate, columns, spring elements, foundation top table and embedded parts). Surface defects are documented (ex. type of defect, dimension, position; photo documentation included) and contained in a report.



Extract of photo documentation: Cracks and concrete spalling.

Further inspection can be carried out with non-destructive tests, i.e. concrete's compressive strength tests (with the Schmidt hammer) or concrete cover determinations (scan instruments).

Left picture: Concrete wall scanning for the detection of embedded objects and the determination of the reinforcement bars (position and concrete cover).
Right picture: Compressive strength tests on a pre-fabricated concrete beam carried out with the Schmidt hammer.

Destructive tests as drill samples can be taken for laboratory analysis, i.e. for the determination of carbonation and chloride content. A co-operation with a local laboratory can be set up; the amount, position and length of the drill samples are discussed in accordance with the customer. The drilling works are to be executed under the supervision of a Trombik Engineer Ltd. representative.

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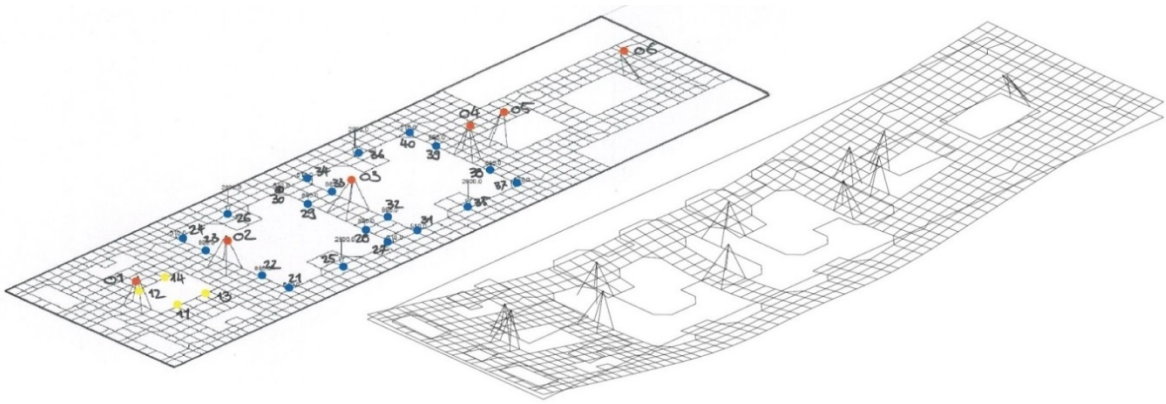
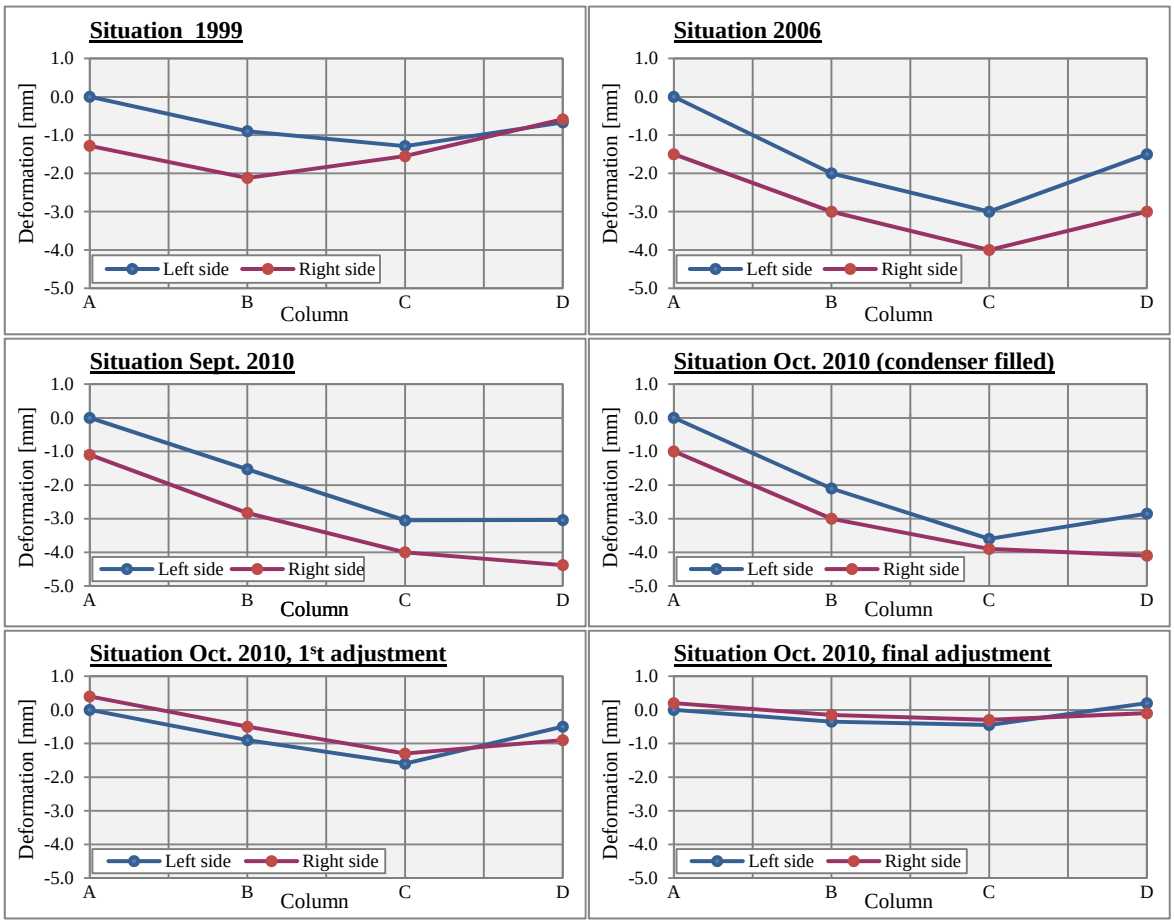
D. EXAMPLE OF TOP TABLE READJUSTMENT



A top table adjustment requires a special Spring-Force-Matrix, which is elaborated by Trombik Engineers Ltd. The displacement matrix models the deformation of the top table caused by the reduction or increase of the Spring Elements load.
The top table adjustment on site is performed under the surveillance of a Trombik Engineer technician. Two to three adjustments including top table levelling checks are usually required in order to reach the desired elevation. The whole process lasts one to two days.



Example of a top table deformation monitoring (1999, 2006, Sept. 2010) and the adjustment steps (Oct. 2010): under certain limits (for example the maximal bearing capacity of the Spring Elements or the stiffness of the concrete plate), the adjustment can be executed according to the customer requirements.