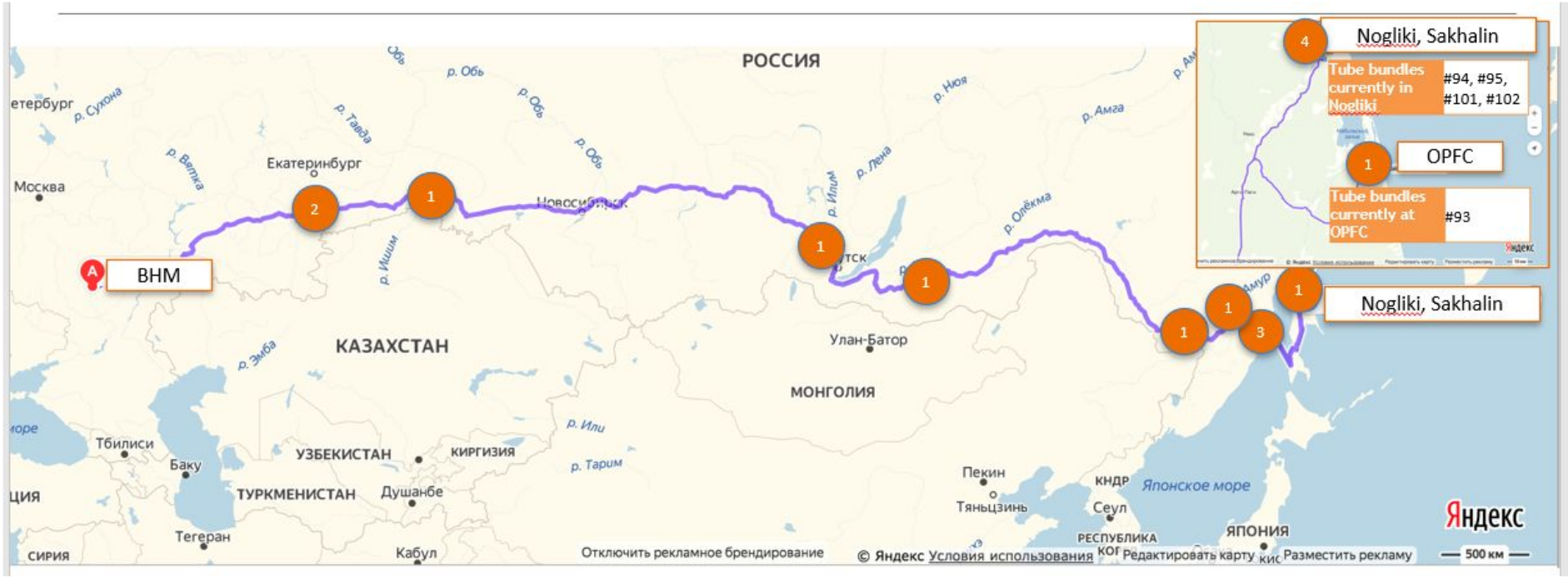
Root Cause Analysis (Tube Bundle)

TO BE THE PREMIER ENERGY
SOURCE FOR ASIA-PACIFIC

БЫТЬ ВЕДУЩИМ ИСТОЧНИКОМ ЭНЕРГИИ
ДЛЯ АЗИАТСКО-ТИХООКЕАНСКОГО РЕГИОНА

Tube Bundles Progress Report



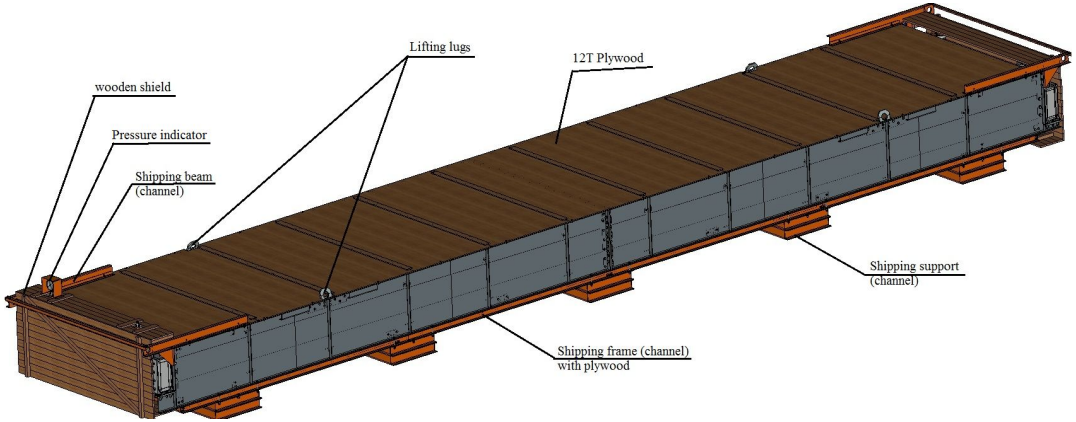
Tube bundle No	#119	#104	#110	#107	#98	#113	#103	#97	#96	#92	#100
Joint #	16	15	14	13	12	11	10	9	8	7	4
Location	Smolino	Smolino	Vkhodnaya	Zalari	Kharagun	Birobidzhan	Komsomol'sk-on-Amur	Vanino	Vanino	Vanino	Poronaysk
Distance to Nogliki	7960 km	7960 km	6960 km	4760 km	3910 km	1560 km	1060 km	785 km	785 km	785 km	325 km

Dispatched – 16 tube bundles; In transit – 11; Arrived in Nogliki – 4 & Delivered at OPFC – 1

Tube Bundle Package Type

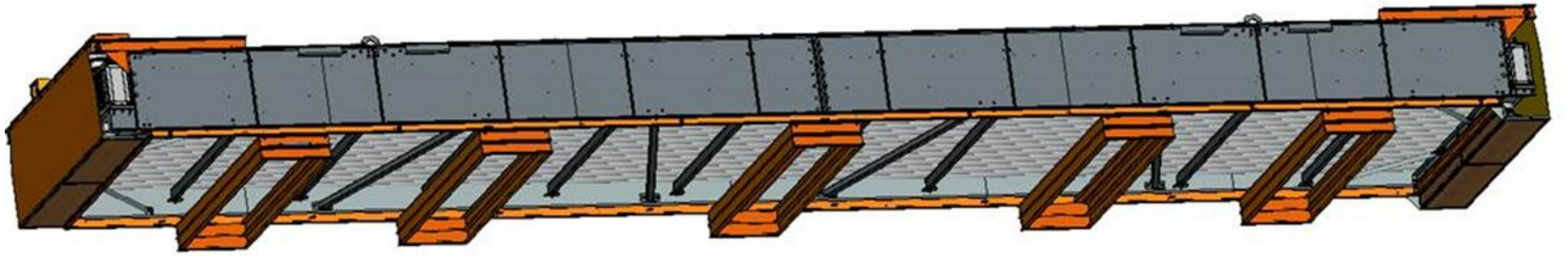
Initial Method of Packing

Section (Tube bundles)
Packing Type: **Metal Frame**
The upper and lower row of finned tubes is covered with plywood with a thickness of at least 10 mm.
The packaging of the tube bundle is wrapped with heavy duty polyethylene tape N2 purged on the top and sides.



Revised Method of Packing

BHM made variations in tube bundle packing, only top protection provided. As well, BHM removed plywood sheets from the bottom of frame.

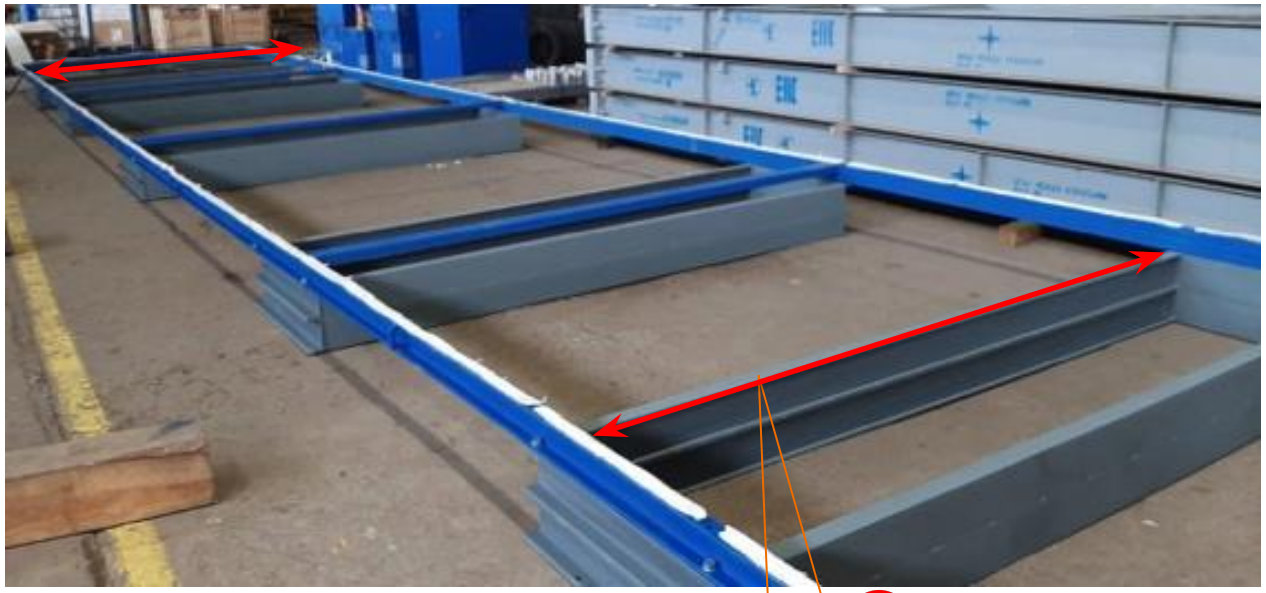


Tube Bundle Frame Design

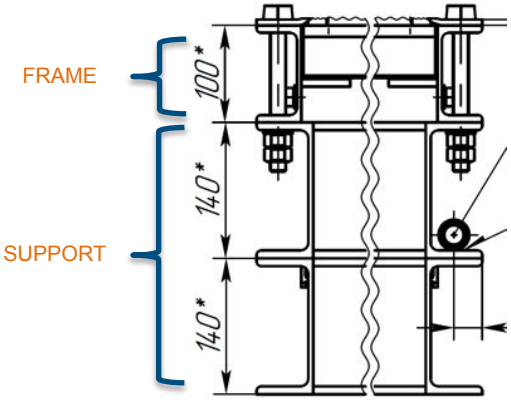
Tube Bundle Frame consists of **5 C-channel supports**
On Picture highlighted the current design of tube bundle frame

Flaws:

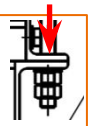
- Missing transversal beams No. 1 and 5 in frame over the support beams and in the lashing points to distribute the weight.
- No 100% overlap: C-Chanel frame shorter than C-Chanel of support



No transversal beams over supports to distribute the weight



No 100% overlap: C-Chanel frame shorter than C-Chanel of support



Experience with BHM related to transport worthy packing

Cargo solidity

In order to perform safe road and rail transport the cargo **package shall be** sufficiently **lashed in accordance with respective mode of transport regulations** and technical conditions to avoid any shifts and/or movements under normal transport process

Cargo inside the package shall be securely placed to avoid any movements inside the package. **Package elements shall undergo structural analysis** to prove it can withstand normative forces applicable to the package during the transport.

For rail transport lashing and dunnage calculations is responsibility of the carrier (Railway Ministry), cargo solidity – is responsibility of manufacturer and shipper (BHM)

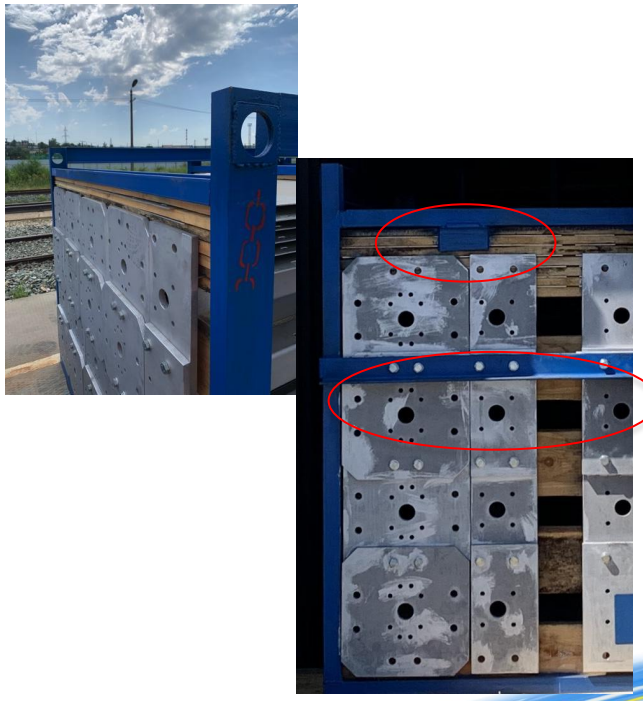
Cases reported on inadequate package

Package A-070-153

Package arrived to Saratov terminal with the cargo visibly damaged. Packages itself remained firmly lashed and did not move during the road transport. The wall sheets were not properly secured against transversal and longitudinal movements. Package shipped back to BHM and package design was re-worked by BHM

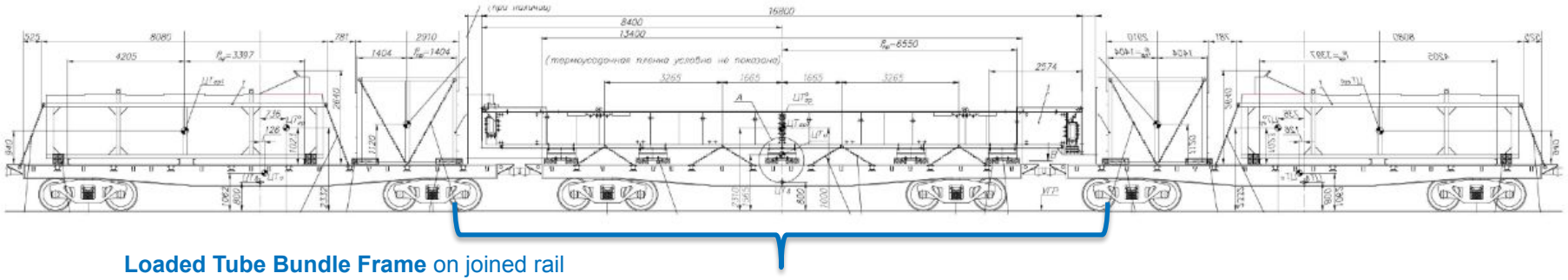
Package A-070-113

Package arrived to Saratov terminal. Upon inspection with rail authorities the questions were raised whether current securing of the cargo inside the frame is sufficient. Kerry addressed the issue to BHM asking to re-check the calculations. Upon rechecking package was deemed not transport worthy and shipped back to BHM. package design was re-worked by BHM before shipping.



Tube Bundle Rail Loading Method

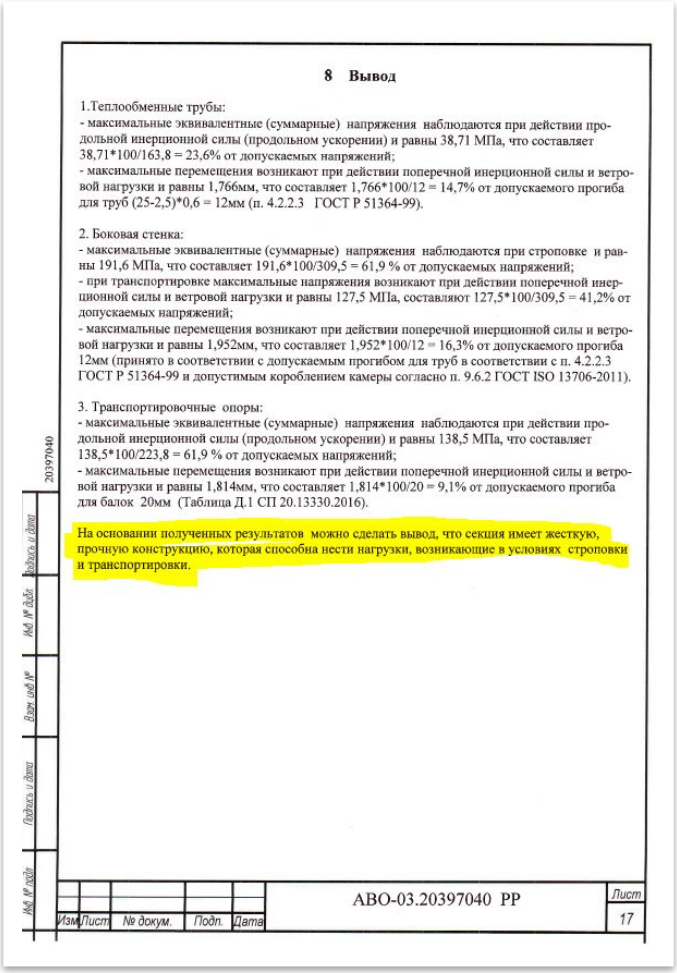
BHM performed Structural analysis (calculation of tube bundle and frame strength) on rail mode of transport. The same document acknowledge that tube bundle w/frame is suitable to be transported in platforms. Accordingly, PFML & Kerry organized safe rail transportation on joint of 3 universal platforms. Based on the same analysis, PFML & Kerry have developed Rail Lashing Schemes.



Loaded Tube Bundle Frame on joined rail platform is placed and fixed on 5C channel supports with wooden beams underneath (tube bundle leaning on the central rail platform)

Structural analysis (calculation of tube bundle and frame strength)

Conclusion of structural analysis given by BHM that tube bundle w/frame can be transported by rail transport



8 Вывод

1.Теплообменные трубы:
- максимальные эквивалентные (суммарные) напряжения наблюдаются при действии продольной инерционной силы (продольном ускорении) и равны 38,71 МПа, что составляет 38,71*100/163,8 = 23,6% от допускаемых напряжений;
- максимальные перемещения возникают при действии поперечной инерционной силы и ветровой нагрузки и равны 1,766мм, что составляет 1,766*100/12 = 14,7% от допускаемого прогиба для труб (25-2,5)*0,6 = 12мм (п. 4.2.2.3 ГОСТ Р 51364-99).

2. Боковая стенка:
- максимальные эквивалентные (суммарные) напряжения наблюдаются при строповке и равны 191,6 МПа, что составляет 191,6*100/309,5 = 61,9 % от допускаемых напряжений;
- при транспортировке максимальные напряжения возникают при действии поперечной инерционной силы и ветровой нагрузки и равны 127,5 МПа, составляют 127,5*100/309,5 = 41,2% от допускаемых напряжений;
- максимальные перемещения возникают при действии поперечной инерционной силы и ветровой нагрузки и равны 1,952мм, что составляет 1,952*100/12 = 16,3% от допускаемого прогиба 12мм (принято в соответствии с допускаемым прогибом для труб в соответствии с п. 4.2.2.3 ГОСТ Р 51364-99 и допустимым короблением камеры согласно п. 9.6.2 ГОСТ ISO 13706-2011).

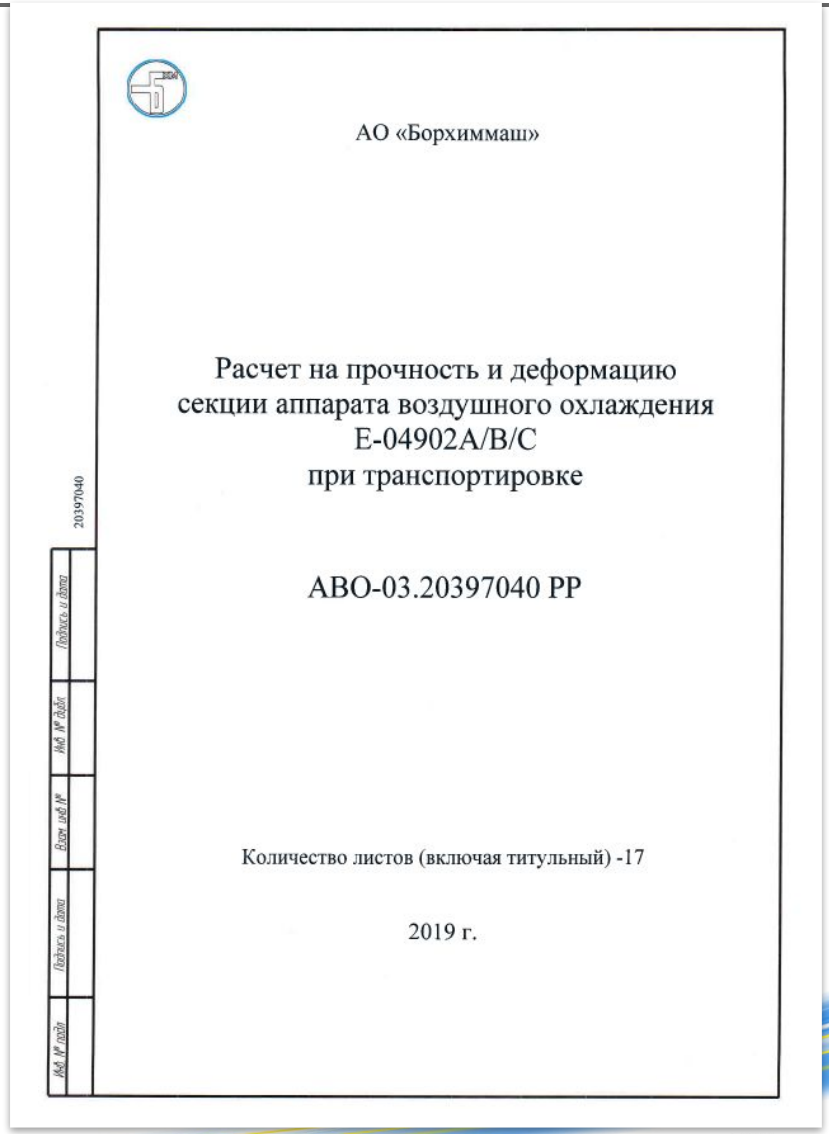
3. Транспортировочные опоры:
- максимальные эквивалентные (суммарные) напряжения наблюдаются при действии продольной инерционной силы (продольном ускорении) и равны 138,5 МПа, что составляет 138,5*100/223,8 = 61,9 % от допускаемых напряжений;
- максимальные перемещения возникают при действии поперечной инерционной силы и ветровой нагрузки и равны 1,814мм, что составляет 1,814*100/20 = 9,1% от допускаемого прогиба для балок 20мм (Таблица Д.1 СП 20.13330.2016).

На основании полученных результатов можно сделать вывод, что секция имеет жесткую, прочную конструкцию, которая способна нести нагрузки, возникающие в условиях строповки и транспортировки.

20397040

Инв. № подл. | Подпись и дата | Взам. инв. № | Инв. № дубл. | Подпись и дата

Изм.	Лист	№ докум.	Подп.	Дата	ABO-03.20397040 PP	Лист 17



АО «Борхиммаш»

Расчет на прочность и деформацию
секции аппарата воздушного охлаждения
E-04902A/B/C
при транспортировке

ABO-03.20397040 PP

Количество листов (включая титульный) -17

2019 г.

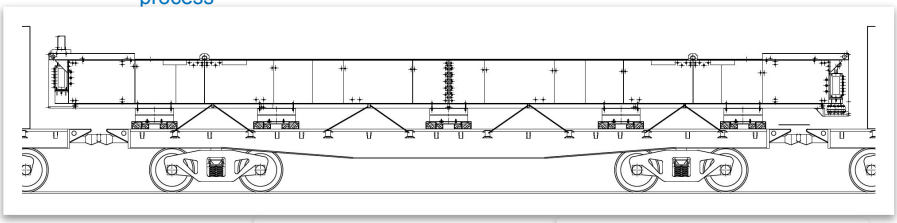
20397040

Инв. № подл. | Подпись и дата | Взам. инв. № | Инв. № дубл. | Подпись и дата

Loading and Lashing Schemes Process

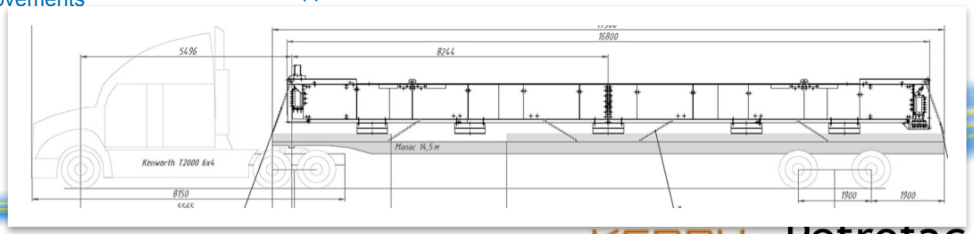
Loading and Lashing scheme development for rail transport

BHM tube bundle package design	Kerry suggestions regarding rail transport	BHM design amendments, tube bundle calculations	Kerry loading and lashing scheme design	BHM review of feasibility, signing	Railway review of the loading and lashing scheme	Approved scheme submitted to BHM
BHM presents package design **suitable for rail and road transport** that satisfies requirements of the **solidity of the cargo**	Kerry presents: - **Request to verify feasibility of support beams' positioning** within 13.2m; - suggestion regarding **adding lashing points** for rail; - request for **calculations necessary for loading scheme** development	BHM **confirms feasibility with calculation**, **amends** final **package design** adding lashing points and placing the supports. The package remains suitable for rail and road, **provides calculations** necessary **for rail transport.**	Kerry provides loading and lashing scheme in accordance with technical conditions (TU-CM943) for BHM review and acceptance	BHM **reviews** the scheme for implementation (acts **as lashing service provider**) and **signs** the schemes **as Shipper** in the rail process	Kerry submits schemes for Railway review and approval. **Railway examine only lashing and dunnage** calculation. **Cargo solidity is BHM responsibility**.	Accomplished exercise Approved scheme



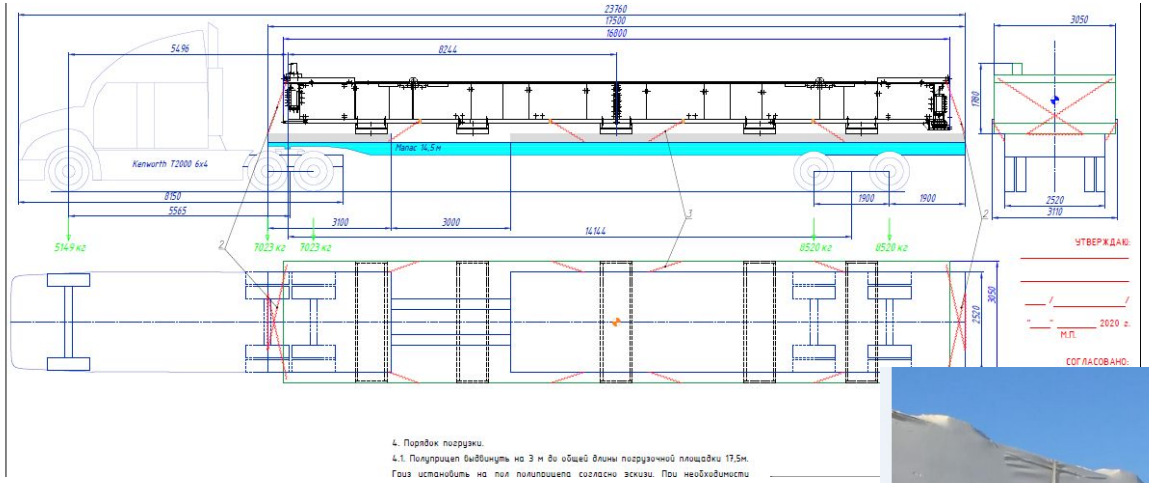
Loading and Lashing scheme development for road transport

BHM tube bundle package design including the frames	Kerry to provide intended transport, loading scheme design	BHM to verify and confirm suitability of Transport design vs. TB Structure integrity	Kerry loading and lashing scheme design finalization	Kerry to obtain Transport permit from relevant authorities. /Transport Agency permit	OOG road permit
BHM presents package design **suitable for rail and road transport** that satisfies requirements of the **solidity of the cargo**	Based on road transport availability, Kerry **requests to verify feasibility of transport on 4 support beams** (#1,3,4 and 5); **provides draft lashing scheme** ↓ The same was utilized, see the next slide	BHM **confirms feasibility with calculation**, suggests adding 4 additional transport belts to protect cargo from longitudinal movements	**Kerry finalizes** loading and lashing **scheme based on BHM input** and provides it to the carriers for review and approval	Carrier submits the scheme and other documents for obtaining ODC road permit to Governmental Control Body	Accomplished exercise ODC permit endorsement



Transshipment operations in Nogliki & Damage Report

Transshipment of Tube Bundle No.93 onto extendable Trailer. Scheme Below



Loading date on 09.12.2020

Arrival to OPFC on 10.12.2020.

Upon transshipment operations of tube bundle in Nogliki, adequate means of transport was utilized, lashing in compliance with BHM guideline and Structural analysis (calculation) performed earlier by BHM on 4 support beams.
It demonstrated on road scheme 4 support beams are acceptable to proceed road transportation. In accordance with comments made the final scheme features 8 belts to protect the cargo against longitude movements.
Photo

Damage Report

Root cause (hypothesis):

Full weight of the tube bundle frame is distributed on the supports' short side of the C-Chanel

Short side C-Chanel receives excess bending force under transport movement

Short side C-Chanel cracks and then collapses dragging tube bundle down.

Collapse of tube bundle on the right side of loading frame support created excessive pressure on the bolts left side which resulted cracks

Tube bundle #93 support #1 damage

Route cause hypothesis:

- There are no transversal beams to distribute tube bundle frame load on the supports;
- Support design relies only on bending stress, not on bearing stress;
- C-shape channel does not function properly due to lack of 100% overlap;

Inspection

Upon the notification of the incident, visual inspection arranged in r/w Nogliki:

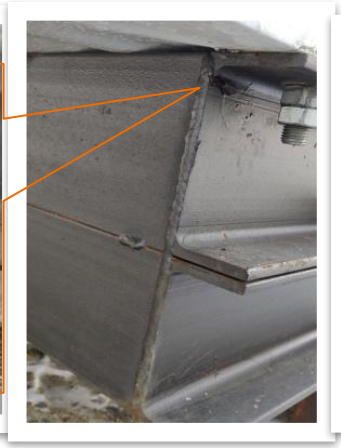
- Visual inspection of 2 other tube bundles #95 and #101 were conducted;
- Tube bundles #94 and #102 supports were closely inspected on the wagons (arrival on 11.12.2020) in order to eliminate possibility of mishandling in Nogliki

Visual Inspection of tube bundle # 102 on rail platforms

Tube bundle #102 support #1 prior to discharge

Visual inspection results: 3 of 4 tube bundles have cracks in the support #1 and C-Chanel bends in other supports

Tube bundle #101 support #1



Tube bundle #95 support #1

Tube bundle #93 support #1 damage

Kerry have visually inspected part of the support beam and found cracks in the transport frame beams (as shown in the pictures).

Condition of Tube bundle in finding on any damages (if occurred) without removal of shrink wrap not possible, Kerry will organize visual inspection in few days time (if requested by BHM & PFML)

Recovery Plan

Safe transport of the not yet shipped tube bundles

1. Suspension of loading & dispatch operations of tube bundles until BHM will re-visit structural analysis (calculations) Reinforcement of the supports and additional structural analysis
   a. Reinforcement plates welding (see below)
   b. Reinforcement backbone welding (see below)
   c. Additional Transversal beams in transport frame

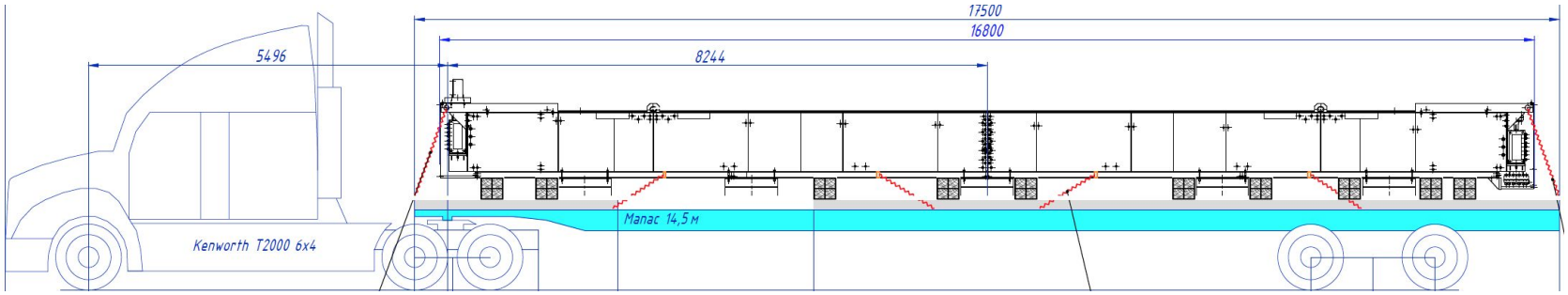
Safe transport of the tube bundles in transit

1. Immediate structural analysis of the supports and evaluation of its results in comparison to technical conditions of Railway acceptance.
2. Rail dispatch to be suspended till calculation to be verified by BHM and if necessary, changes in current design of the beam
3. Road transport scheme overhaul
   a. Reinforcement of the supports
   b. Use of wooden beams supports lean on the frame (see below scheme)

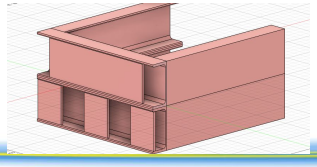
Safe transport of the damaged tube bundle to repair shop (proposed by Kerry)

1. Tube bundle condition evaluation
2. Development of the dedicated transport plan
3. Road transport is preferable with shorter transit time and less risk of damage in transit.
4. Timeline for transport preparation:
   a. Evaluation of transport conditions 5 days
   b. Development of transport supports and transportation scheme, route survey 15-20 days
   c. Transit time 25-30 days
   d. Backload Transit time 25-30 days.

Road transport with wooden beams option 3b.



a.



b.