Anna KOCHANEK[1], **Karol PLATA**[2]

[1] University of Applied Sciences in Nowy Sącz, Faculty of Engineering Sciences, Zamenhofa 1a, 33-300 Nowy Sącz, e-mail: akochanek@ans-ns.edu.pl
[2] University of Applied Sciences in Nowy Sącz, Faculty of Engineering Sciences, Zamenhofa 1a, 33-300 Nowy Sącz, e-mail: karoleuro5@interia.pl

Conceptual design of an unloading system for the T60 medium

Abstract

This paper is devoted to conceptualising a new system for the rapid and safe unloading of the hazardous medium T60. The most important legal acts, related to the transportation and unloading of hazardous substances include: the European Agreement concerning international carriage – Road Transport of Dangerous Goods (ADR), the Act on Transport of Dangerous Goods – ADR standard, and the regulation of the Minister of Transport dated 20 September 2006. In the first stage of this work, we find a description of a tanker vehicle in which the T60 is transported. Then there is a description of the medium T60, a hazardous substance from which electrodes are produced. The description of the tanker and the substance was prepared on the basis of the company's internal documentation. The last stage was to describe a conceptual design for an unloading system for T60, using the latest technology, which will reduce the unloading time and increase the efficiency of the current unloading system. In order to best design the unloading system in question, a unique in-house program was used. Based on the calculated parameters, the individual components of the unloading system are selected, i.e. pump, motor, pipes, wedge gate valve, the main safety switch, and ground continuity control system. Then a technical drawing was prepared of the pump unloading system, showing the technical connection of the motor to the pump and a diagram of the unloading system connection to the tanker.

Key words: T60 medium, system for unloading, tanker FFB, ADR, hazardous substance.

Projekt koncepcyjny systemu rozładunkowego dla medium T60

Streszczenie

Niniejszy artykuł poświęcony jest koncepcji nowego systemu służącego do szybkiego i bezpiecznego rozładunku substancji niebezpiecznej T60. Do najważniejszych aktów prawnych, związanych z transportem oraz rozładunkiem substancji niebezpiecznych, należą: *Umowa europejska* dotycząca międzynarodowego przewozu drogowego towarów niebezpiecznych (ADR), ustawa o przewozie towarów niebezpiecznych – norma ADR oraz rozporządzenie Ministra Transportu z dnia 20 września 2006 roku. W pierwszym etapie niniejszej pracy znajduje opis cysterny, którym transportowana jest substancja T60. Następnie przedstawiony został opis medium T60, czyli substancja niebezpieczna, z której produkuje się elektrody. Opis cysterny i substancji opracowano na podstawie dokumentacji wewnętrznej firmy. Ostatnim etapem było opisanie projektu koncepcyjnego systemu rozładunku substancji T60, wykorzystując najnowszą technologię, która zredukuje czas rozładunku oraz podniesie wydajność obecnego systemu rozładunkowego. W celu jak najlepszego zaprojektowania przedmiotowego systemu rozładunkowego, do obliczenia najważniejszych parametrów systemu wykorzystano specjalny program wewnętrzny firmy. Na podstawie obliczonych parametrów przeprowadzony został dobór poszczególnych elementów systemu rozładunkowego, czyli dobór pompy, silnika, przewodów, zasuwy klinowej, głównego wyłącznika bezpieczeństwa i układu kontroli ciągłości uziemień. Następnie opracowano rysunek techniczny systemu rozładunkowego za pomocą pompy, przedstawiający techniczne połączenie silnika z pompą oraz schemat podłączenia systemu rozładunkowego do cysterny.

Kluczowe słowa: czynnik T60 medium, system rozładunku, cysterna FFB, ADR, substancja niebezpieczna.

1. Introduction

The purpose of this article is to develop a new unloading system for the company. Medium T60 is a substance – binder pitch SP 84, which on the basis of the European Agreement Concerning the International Carriage of Dangerous Goods by Road is assigned the article number P11. T60 serves as a binding agent for the production of carbon electrodes. In addition, the article states that T60 is supplied by VFT Poland Sp. z o.o., which has its registered office in Kędzierzyn-Koźle. However, the T60 medium consists of a complex mixture of polycyclic aromatic hydrocarbons and heterocyclic hydrocarbons (Blank, 2009). Table 1 shows the chemical composition of T60.

Table 1
Chemical composition of T60 medium

Composition marking	Name of component with hazard class	Percentage content of substance [%]
CAS: 65995-93-2 EINECS: 266-028-2	High temperature coal tar pitch carcinogenic	>50
CAS: 50-32-8 EINECS: 200-028-5	Benzopiren carcirogenic cat. 2, Muta. Kat 2, Repr. cat. 2	<2,5

(source: authors' own compilation based on: Material Safety Data Sheet – RUTGERS)

Based on the European Agreement Concerning the International Carriage of Dangerous Goods by Road, T60 is a hazardous substance. This substance can cause: the induction of cancer, the inheritance of genetic defects, foetal impairment in the womb and very severe environmental contamination. For this reason, a number of procedures and instructions for handling the substance are also described. In particular, the greatest caution should be exercised during contact with the skin, the eye or when inhaling vapours, as T60 causes severe burns or irritation of the skin or mucous membranes. During a fire, carbon monoxide or PAH may be released. On the other hand, in the event of environmental contamination, the main thing to do is to prevent the substance from entering sewers or water bodies. This is to prevent heavy surface contamination of the environment over a wide area. In the event of a T60 spill, the situation must be reported immediately to the relevant authorities, as the substance is very difficult to dispose of.

Another very important aspect is the storage of T60. This substance requires special storage conditions, i.e., high-temperature silos that are airtight and dry. Based on the Requirements concerning the construction and approval of vehicles, it can be specified that the unloading area should be adequately ventilated. Persons in the vicinity of the substance described should be equipped with respiratory filtering devices that have a P3 filter, protective gloves bearing the CE mark of category III, sealed safety goggles and protective clothing. The physical and chemical properties of T60 are shown in Table 2.

Table 2
Physico-chemical properties of T60

Material:	liquid
Colour:	black
Scent:	pungent
Boiling point:	>300°C
The range of softening:	60-70°C
Ignition point:	>190°C
density:	1 250-1 300 [kg · m^{-3}]
Temperature of decomposition:	400°C

(source: authors' own compilation based on: Material Safety Data Sheet – RUTGERS)

The transport of T60 is also an important aspect. The substance is only approved for land and sea transport. According to Rogalski, the transport of the substance to the production facility is one of the most important production steps. Any stoppage of the production line is highly disadvantageous. The material must be kept in a liquid state at 100º C, in a 100,000 [l] capacity tank, which is heated by heating oil supplied from an oil-fired boiler plant through a system of four coils mounted in the lower part of the tank. The T60 medium is transported using FFB-brand, high-temperature, single-chamber road tankers. Tankers intended for the transport of T60 must comply with strict safety standards set by the Transport Technical Supervision. These tankers do not have their own temperature support system and therefore operate like a "thermos". As a result, it is important to select the correct temperature at the loading stage, taking into account the time needed to transport the substance. If the temperature of the material is too low, the unloading pipes can become clogged or even freeze the road tanker completely. In order to classify a medium as a hazardous load, it is necessary to have a safety data sheet (SDS), which is required by the Road Transport Inspectorate and other official authorities. The SDS is also defined by Regulation 1907/2006/EC, which justifies that the SDS is the main means of communication between the manufacturer, supplier and other users in the logistics chain (Grzegorczyk, Buchcar, 2021). Table 3 shows the T60 classification used for each mode of transport.

Table 3
Classification of T60 as applied to individual modes of transport

Sea transport	Land transport ADR/RID
class: IMDG/GGVSee: 9 Number UN: 3257 Label: 9 + ET Packaging group: III Number EMS: F-A, S-P Proper technical name: Elevated Temperature Liquid, N.O.S.	Packaging group: III Name of product: 3257 Material: heated, liquid, I.N.O. (Hydrocarbons, liquid)

(source: own compilation based on: Material Safety Data Sheet – RUTGERS)

According to Łuszczak, the transport of hazardous materials must remain classified, i.e., each type of hazardous material is assigned a UN number and name, and transport conditions based on the comparison of the chemical, physical and biological properties of the material with the ADR classification criteria. Each UN number assigned is governed by a regulation of the European Parliament and of the Council. This regulation divides hazardous materials into 13 classes.

2. The selection of unloading system components and development of a conceptual design for unloading the T60 medium

The T60 unloading system will be developed for a company that manufactures carbon electrodes and uses T60 for their production. The company currently uses a vacuum discharge system for T60. Data on discharge systems for hazardous substances indicate that the most efficient and safe method is to discharge the substance using a pump. It is important to choose the right type of pump for the material in question, as each material has individual physical and chemical parameters. The choice of pump is made on the basis of calculations relating to the pump's maximum delivery head, pump capacity and the calculation of hydraulic losses in the system and the diameter of the pipes. The calculations for the most important parameters of the discharge system were made on request. Figure 1 shows a schematic of the system used to discharge the T60.

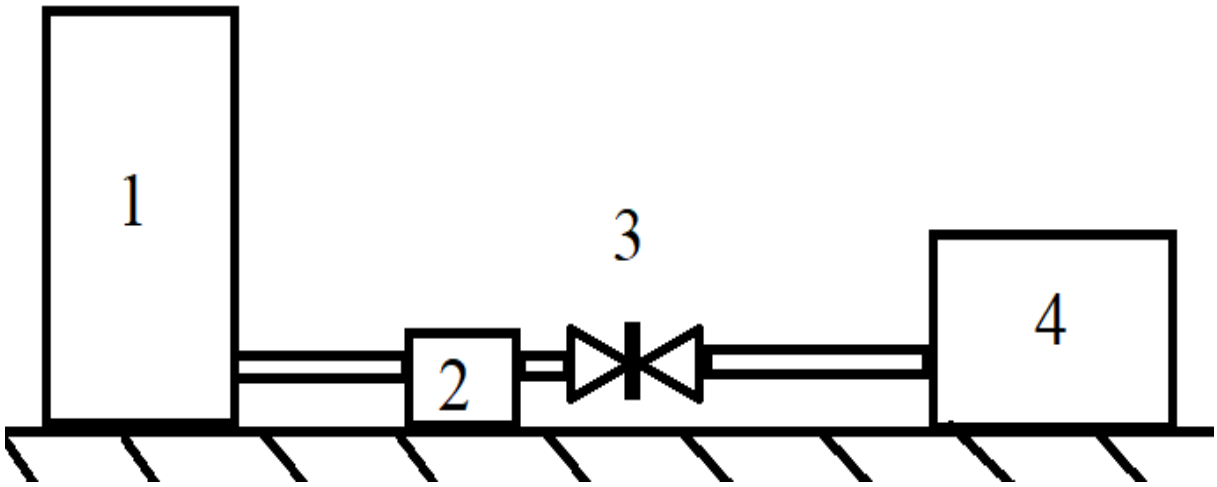

Figure 1. Diagram of the T60 unloading system

(source: authors' own elaboration based on zamkon.pl)

Elements of the conceptual unloading system:
1 – silo;
2 – pump;
3 – wedge valve;
4 – road tanker.

2.1. Selecting components for the conceptual design of an unloading system

The unloading pump and the motor driving the pump are one of the main components of the designed unloading system at the company site. The operation of the system also requires a cable, a wedge gate valve, a main safety switch and a ground continuity control system.

The various components were selected based on calculations that were commissioned by the company. The results of the calculations have not been published, as they constitute technical information that is a company secret.

The first component selected is a conduit for transporting material to the pump and then to the silos. The main technical requirements that such a duct must meet are determined by the technical parameters of the unloading pump and the properties of the T60 being transported:

- internal working temperature: from 80°C to 120°C;
- external operating temperature: from (-20)°C to 50°C;
- working pressure: up to 3.5 [bar];
- test pressure: 1.5 [MPa];
- minimum service life: up to 7,500 operating cycles.

Based on the above data, a hose from Tubes International with the catalogue number, internal TB-PARNOR-80, was selected (Figure 2).

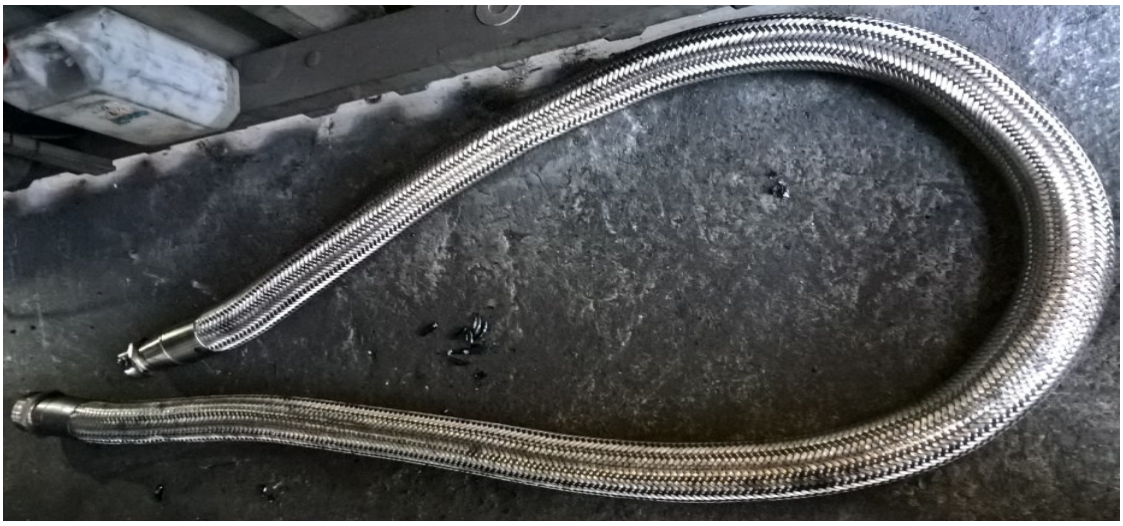

Figure 2. Tubes International's TB-PARNOR-80 unloading hose
(source: authors' own elaboration based on Tubes International catalogue)

It is a pressurised steel hose used for transporting chemicals under pressure and in high vacuum conditions. It meets the requirements contained in ISO 10380. Table 4 shows the technical data for the selected discharge hose.

Table 4
Technical data for the selected unloading hose TB-PARNOR-80 from Tubes International

Index	DN [mm]	External diameter [mm]	Dynamic conditions		Static conditions	
			Working pressure [bar]	Minimal bending radius [mm]	Working pressure [bar]	Minimal bending radius [mm]
TB-PARNOR-080	80	102,6	23	660	30	240

(source: authors' own elaboration based on Tubes International catalogue)

The service life of the hose under the conditions described in EN ISO 10380 is 50,000 bending cycles at maximum operating pressure for dynamic conditions. The inner layer of the corrugated hose is made of 321 steel, while the reinforcement is made of single braid 304 steel. The operating range is from (-270)°C to 800°C.

The second selected component of the unloading system is the Zamkon brand wedge gate valve with reinforced mandrel. The purpose of using a wedge gate valve is to enable, in the event of a failure, the material supply to the unloading pump to be shut off. The valve is located directly upstream of the unloading pump. Table 5 shows the specifications of the wedge valve.

Table 5
Technical specifications of the wedge gate valve DN80-600, Zamkon company

Nominal pressure:	1,6 [MPa]
Max. permissible temperature:	425°C
Materiał:	Carbon steel GB240GH
Weight:	28 [kg]
Maximum test body pressure:	2,4 [MPa]

2.2. The selection of pump including motor for unloading T60 medium

The appropriate selection of the unloading pump is the most important part of the unloading system. A suitable pump was selected based on the T60 data sheets, where one of the main design requirements is a temperature resistance of up to 100°C. In addition, the entire unloading system – including the pump – should be equipped with a NO device with an electrical heating system, which will effectively prevent the material from losing heat. The unloading pump and all components should include thermal insulation characterised by resistance to the material being handled, suitable thermal conductivity and mechanical properties, and by being fireproof.

One of the few pump manufacturers meeting the requirements necessary for transporting T60 is VARISCO. Taking into account the capacity of the unloading system, the maximum head, the maximum length of the hose and the temperature, the Varisco V80-2 unloading pump was selected, which is shown in Figure 3. The pump's technical data are described in Table 6.

Figure 3. Varisco V80-2 unloading pump

(source: compiled from: variscopompy.com)

Table 6

Technical data of the Varisco V80-2 brand unloading pump

Nominal flow rate:	70 [l ·s^{-1}]
Maximum differential pressure:	16 [bar]
Temperature range:	(-60)°C do 300°C
Connection dimensions:	80 [mm]
Unit capacity:	1,200 [l ·obr^{-1}]
Weight:	84 [kg]
Capacity:	33 [t ·h^{-1}]
Working pressure:	8 [bar]
Gear motor:	Nord; 15 [kW]; min. 1000 [obr ·min^{-1}]; 400 [V]

The Varisco V80-2 unloading pump is an internal gear centrifugal pump. This type of pump allows for continuous flow. This is a very important part of the unloading system, as any irregularity in the pump's operation can lead to damage to the unloading system on site. In addition, the pump has a simple design, which enables quick and inexpensive servicing.

The principle of operation of the described pump is based on the principle of displacement. The rotor is driven by a further rotating rotor. The fluid to be pumped is then drawn into the free spaces between the gear teeth. A crescent-shaped section seals the gap between the gears as the material is pushed towards the discharge side. The substance is then forced into the discharge port. The result is a uniform flow without pulsation. In order for the pump to achieve a capacity of 33 [$t \cdot h^{-1}$], where the density of T60 is 1 300 [$kg \cdot m^{-3}$], it must be driven by a motor that meets the following minimum requirements:

- power output min. – 15 [kW];
- rotational speed – 1 355 [rpm^{-1}];
- rated torque – 98.45 [Nm];
- voltage – 400 [V].

The technical data of the Nord brand three-phase motor, working with the Varisco V80-2 unloading pump, are shown in Table 5.

Table 7
Technical data of the Nord brand engine

Type of attachment:	Paw and Collar
Shaft diameter:	42 [mm]
Number of revolutions per minute:	1 455 [turnover·minutes-1]
Direction of rotation:	Left/Right
Power output:	15,0 [kW]
Voltage:	400 [V]
Torque:	100 [Nm]
Cable glands:	M32x1,5
Permitted axial load:	2 399 [N]
Permitted radial load:	2 981 [N]
Noise level:	75 [dB]
Permissible ambient temperature:	From (-20)°C to 40°C

The use of the Varisco V80-2 unloading pump will allow the T60 to be unloaded in a period of 3,600 [s], which is up to 1,800 [s] faster than the vacuum unloading system. In summary, the unloading pump will enable 500 [kg] of T60 to be unloaded in 60 [s].

3. Technical drawing development

The technical documentation of the unloading system using a centrifugal pump is presented in two technical drawings. The technical drawings were developed using the integrated CAD programme CATIA. Figure 4 shows the T60 unloading system.

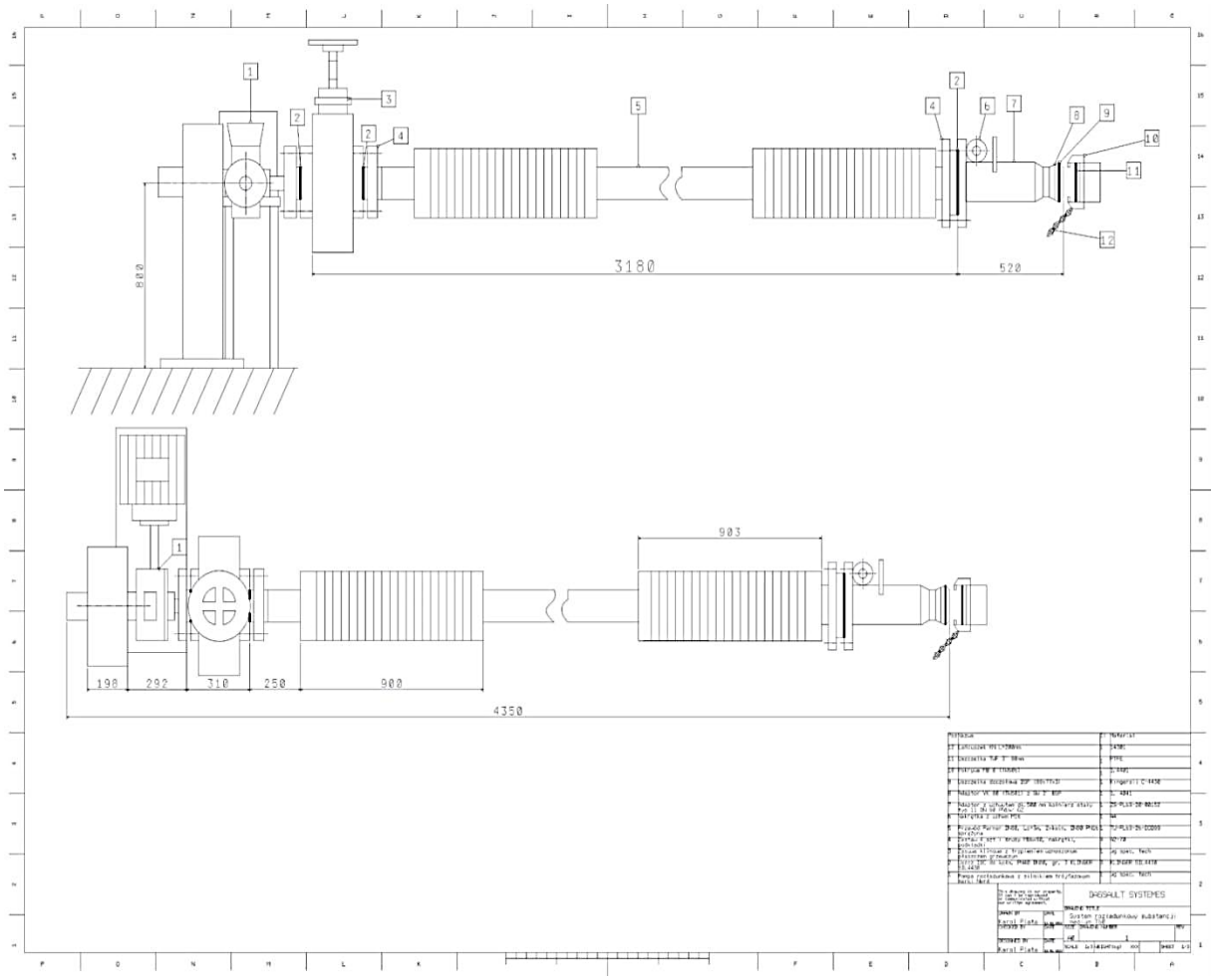

Figure 4. Technical drawing of the T60 unloading system

(source: authors' own elaboration)

The system, from the right, consists of the MB 80 lid, which is used to close the unloading system. The MB 80 lid is equipped with a chain, which secures the lid when the unloading system is opened, and a TWF 3 seal. Subsequently, the unloading system is equipped with: butt seal, VK 80 adaptor, DN 80 PN16 bracket adaptor, M16 bracket nut, Parnor DN 80 pipe, DN80-600 wedge gate valve, set of four bolts, IBC gasket for flange, Varisco V80-2 centrifugal pump, Nord sinus and reinforced top with metal supports for the pump and motor. The unloading system transports the T60 from the tanker, via hoses and pump, to the Tubes International brand silos, designated TB-PARNOR-80. Figure 5 shows the zone of connection of the unloading system to the tanker.

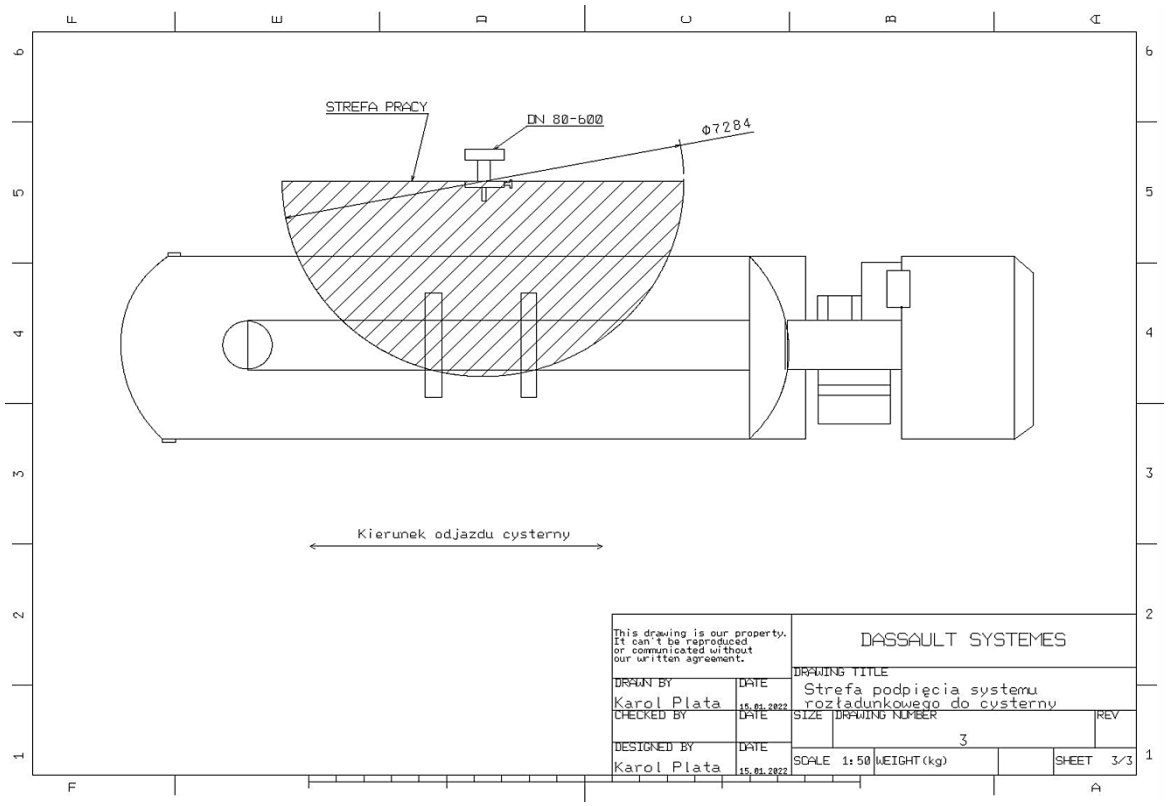

Figure 5. Technical drawing of the connection of the unloading system to the tanker

(source: authors' own elaboration)

4. Conclusions

The conceptual design of the unloading system was carried out on the basis of the T60 data sheet, where a centrifugal pump, brand Varisco V80-2, was selected for the unloading of T60. Due to the specific material, T60, the design of the unloading system by means of the pump was developed under the supervision of a specialist from the electrode manufacturing company. The T60 discharge system consists of a cable, a wedge gate valve, a main safety switch and a ground continuity control system. The hose selected is a steel--pressure hose, which has an inner layer made of 321 steel. The reinforcement of the unloading hose is made of single braided 304 steel, which has an operating temperature range from (-270)°C to 800°C. This high temperature range allows the device to have a long service life, as the temperatures at which the discharge tube will operate are not the limit. Another selected component of the unloading system is the wedge gate valve DN80-600, from Zamkon. This serves to close the material supply to the unloading pump in the event of a valve failure in the tanker. The unloading system also features a main safety switch manufactured by the Polish company Schneider Electronic, which is intended to shut down the three-phase motor driving the centrifugal pump. The switch will be located in a prominent position directly above the NO unit.

All the factors discussed above and the equipment selected will allow a reduction in unloading time, which is a very important aspect. Through the new unloading system, operational safety will also be improved. Through the use of a NO device with a heating system, the temperature of the substance will not drop during the unloading of T60. As a result, the correct chemical properties of the T60 medium will be maintained during unloading.

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