

Marek Ł. GRABANIA
Michał GRABIŃSKI

PMC - LEGUAN ASSAULT BRIDGE

Abstract. The article describes the design of the PMC - LEGUAN assault bridge/tactical bridge on tracked chassis developed by OBRUM and Bumar-Łabędy S.A. for export to Malaysia. Basic technical and performance specifications of the LEGUAN bridge span are listed in a table. The design of the main structural units determining the optimal union of the PT-91M chassis with the LEGUAN bridge spans is discussed. In conclusion, reference is made to the final results of the completed research and production launch tasks.

Keywords: mobility of troops, crossing, Malaysian contract, assault bridge, PT-91M tank, LEGUAN bridge, PMC-LEGUAN bridge.

1. INTRODUCTION

One of the most important tasks of engineer troops is to ensure the desired mobility of troops. Specialized equipment, bridges of various types: transportable, foldable, pontoon bridges, enables the army units to negotiate obstacles in the terrain, both water obstacles (streams, creeks, rivers), as well as land obstacles (pits, ravines, gorges, etc.). Selection and sizing of proper equipment of defined technical and performance specifications depends on the anticipated areas of operation and on defined obstacles that may be encountered. The various equipment used by the armies of the world and the various types of bridges are discussed in [1]. Currently, one of the most modern technical solutions is that of transportable bridges of various span lengths, set on a wheeled or tracked chassis, launched and retrieved from an obstacle, usually in automatic mode, with minimum human intervention. There is, however, often the need to prepare the crossing in advance: approach to obstacle, area levelling, or covering party for the crossing consisting of combat troops [2], [3]. Bridges are classified according to the manner of their use. Thus, assault, combat and support bridges are integral components of forward combat formations. Other bridges, used within the formation or at behind the lines, are classified as tactical or logistic bridges. They are used, among others, to build permanent or temporary crossings over broader water obstacles to ensure the redeployment of troops, delivery of supplies, evacuation of personnel and equipment. Fig. 1 is a diagram illustrating the conventional classification of bridges.

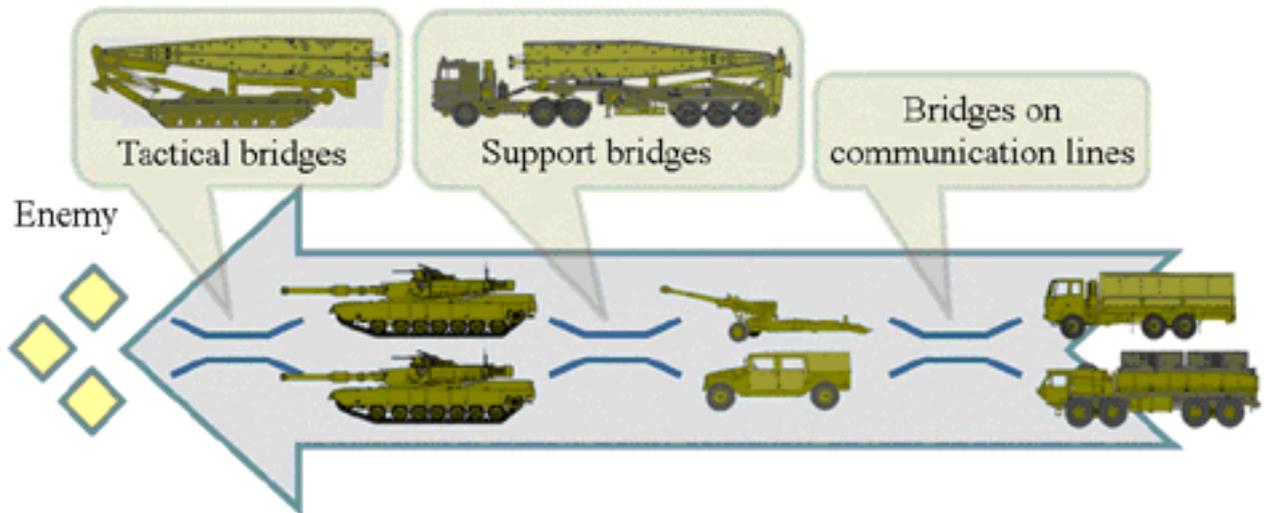


Fig. 1. Bridge classification

2. THE MALAYSIAN CONTRACT

In 2003 the BUMAR holding, which included the major companies of the Polish defence industry, signed a contract for the delivery of armoured equipment to Malaysia [4], [5]. The main contractors were Bumar - Łabędy S.A. and OBRUM. As part of the delivery of equipment for the Armed Forces of the Kingdom of Malaysia, the contract provided for the development and manufacture of forty-eight PT-91 M main battle tanks, six WZT-4 recovery vehicles and three MID-M engineering tanks. The contracting party considered it necessary to retrofit the purchased equipment also with self-propelled bridges, five of which were ordered. After the analysis of the state of the art, the contractor chose a transportable bridge (designated in the contract as PMC-LEGUAN) based on the retractable spans [1], [6] of the German company MAN, installed on and integrated with a tank tracked chassis. The chassis was that of the PT-91 M tank (main subject of the contract) which constituted the fabrication basis for specialized vehicles. The basic requirement for all vehicles covered by the contract, spin-offs of the tank, was that to standardize the components, including the tracked chassis.

3. LEGUAN ASSAULT BRIDGE

The design and implementation work carried out by Polish engineers was supervised by a team of Malaysian military specialists delegated to Poland. In the initial phase of the consultations (the conceptual design phase), the Polish side proposed, as part of the contract, the delivery of the existing PMC-90 bridge with "scissors" type spans installed on the PT-91 M chassis. This solution, however, was not accepted; the Malaysian partner chose a solution that the Polish side did not offer, namely the German bridge LEGUAN, used by the US, German and Spanish armies. The transportable LEGUAN bridge with extendable spans is installed on such tank chassis as those of M1A1/A2 (USA), Leopard 1 (Germany) and M60/M47 (Spain) [6]. The manufacturer of the bridge span was MAN Technologie AG [6] (now Krauss - Maffei Wegman KMW), which also became the supplier of the bridge spans. The selected bridge was made of aluminium alloys, and therefore its weight was low as compared to other transportable bridges. Basic specifications are listed in Table 1.

Table 1. Specifications of the LEGUAN bridge

Parameter	Value
Construction material	Aluminium alloy
Bridge length	26 m
Bridge weight	10.5 t
Bridge class (MLC)	70
Effective length of span	25 m
Bridge width	4.01 m

The German contractor's scope of delivery included, in addition to individual spans (4 spans for every vehicle), mechanical components of the bridgelay (including front and rear arms) complete with control elements, main hydraulic actuator, hydraulic and electric system, control system with operating panel.

The LEGUAN spans installed on a German tank chassis are shown in Fig.2. In the front part of the hull there is an extendable support for stabilising the arrangement during launching and retrieval of the span from an obstacle.



Fig. 2. KMW LEGUAN bridge (LEOPARD 1 chassis with seven pairs of road wheels)

4. PMC - LEGUAN

Arrangements and design work required the collaboration of three teams: Polish (Bumar-Łabędy S.A. and OBRUM), Malaysian (final user) and German (MAN Technologie AG - manufacturer and supplier of bridge spans and bridgelay along with power hydraulics and control system). The adopted variant of the assault bridge with extendable spans required the Polish side to carry out design works, among them:

- development and agreement on the installation of LEGUAN bridge spans on PT-91 M chassis;
- weight calculations of the set under design;
- computation of stability of the span-chassis set in all stages of launching, taking into account the impact of wind pressure and slope of the terrain;
- designing the front/bank support, including ensuring visibility to the driver;
- design and construction of the mechanical-hydraulic system for launching the bank support;
- design of the hydraulic system and consolidation thereof with components provided by the German party;
- design and construction of the drive system for the main pump of the hydraulic system powered from the main engine (power pack) PTO;
- connection of the electrical and control systems of the tank chassis with the bridge spans;
- layout of the additional equipment and spare parts without affecting stability;
- optimization of the weight of the bridge-chassis set (combat weight, including final equipment) to no more than 50 t;
- preparation of technical documentation of the final design – the supplied version of the PMC – LEGUAN assault bridge.

4.1. Stability of the chassis-bridge spans set

The concepts of the installation of the LEGUAN bridge span on the PT 91 M chassis included:

1. 7-wheels chassis with geometry similar to that of PT-91 M chassis.

This variant improved the L/B ratio: it increased the ground contact length of the bottom run of the track. As a result, the driving comfort could be improved - limiting the galloping, better driving conditions during acceleration and braking.

2. 6-wheels chassis with larger wheel spacing, which also increases ground contact length of the bottom run of the track and helps attain features as in item 1.
3. 6-wheeled version, identical wheel spacing as in PT-91 M chassis, with bank support installed at the front (OBRUM's proprietary design – Figs. 3 and 4).

4.2. Weight analysis

One of the basic requirements specified in the contract was the maximum total weight of 50 t of all vehicle versions, including MBT with complete combat equipment.

Stability analyses were carried out [7] for all of the three versions described in section 4.1. Weight analyses were also carried out simultaneously [7]. These indicated, in the case of some attachments, the need to use additional load to maintain the stability of the bridge-chassis set. This obviously was not acceptable. Upon the analysis of calculation results [7] version 4.1.3 was adopted for further design work.

Analyses and design studies [7] of the bridge with LEGUAN spans showed that the 50-tonnes limit would be a big challenge for the design engineers. As a result the German supplier fabricated bridge spans of lower weight. However, this version of LEGUAN spans for the Malaysian client reduced the bridge load class to MLC 60 [8], while the standard version was 70 MLC – Table 1. This change required special arrangements and making amendments in the contract documents.

4.3. Kinematics of the bridgelayer

The PMC-LEGUAN bridge with extendable spans is characterized by a complex algorithm of span launching and retrieval. The process is monitored by the operator using an operating panel with a display. The manner of launching an extendable span over an obstacle (main stages) is shown schematically in Fig. 3. The operation of the bridgelayer, the most important unit of the bridge, can be effected [9] in four modes::

- manual;
- semiautomatic;
- automatic;
- package mode.

Switching between automatic and semiautomatic and between automatic and manual mode is possible at any time. However, switching between manual and semiautomatic/automatic mode is possible only under certain circumstances.

Proper operation of the bridgelayer requires maintaining defined values of stability factors (longitudinal and transverse stability defined in standards: PN-87/M-06513/PN ISO 4305), taking into account the impact of wind pressure. The basic problem in the stability analysis is the analysis of geometrical and physical properties, that is determination of the proper mass distribution in the structure at the most unfavourable stage of launching the spans. The load variant most unfavourable for stability was adopted, i.e. the bridge position during launching before it rests on the ground (Fig. 3c). The condition of longitudinal stability [7], in the case of 6-axle chassis, required the introduction of an additional stabilizing element: a bank support.

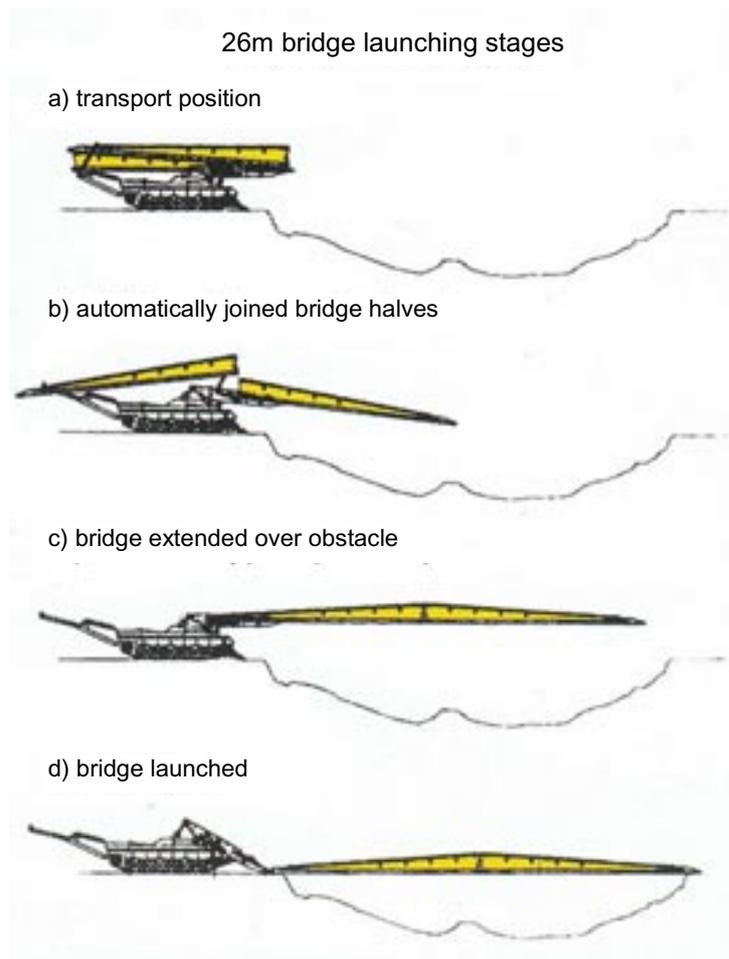


Fig. 3. Key phases of launching the bridge span over an obstacle [6]

4.3.1. Bank support

The bank support installed in the front part of the PMC-LEGUAN chassis is launched and retrieved by means of two pairs of hydraulic cylinders energized from the main hydraulic system. The support installed on the front part of the chassis is shown in Fig.4.

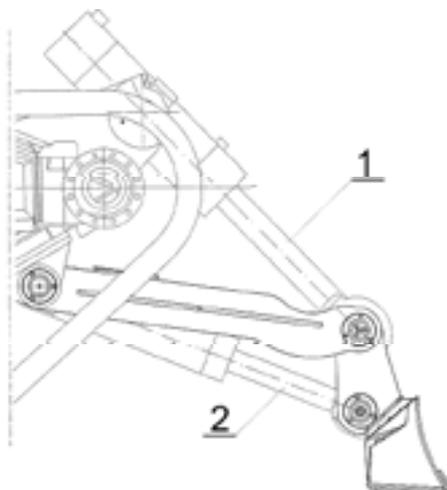


Fig. 4. Bank support – side view

1 – upper actuator, 2 – lower actuator

The design of the bank support developed at OBRUM differs significantly from existing solutions. Its installation in the body of the vehicle, with the driver's seat being located at a certain height resulting from the design of the chassis, must have not caused any reduction of the driver's field of view. An additional difficulty was that the vehicle would be used in a country where left-hand traffic was in force. In order to adapt the support structure to the traffic requirements, special simulations were carried out to select the most favourable design. As a result, an "articulated" type structure was created which, after carrying out a series of strength calculations and determining geometrical dimensions defining the support point of the set during the launching and retrieval of the span, underwent factory and field testing. Preliminary tests of the support were carried out using a WILK tank chassis. Fig. 5 shows the designed bank support during preliminary field testing.



Fig. 5. Bank support of the PMC - LEGUAN bridge during preliminary testing

4.3.2. Installation of the bridgelayer

In order to ensure the required kinematics of the bridge launching and retrieval process and proper mass distribution of all components constituting the PMC - LEGUAN set, the PT-91 M hull was redesigned. To this end special frames were built into the hull to provide the desired strength of the body and to allow for the correct kinematics of the movements of the bridgelayer, including that of the main actuator. All design work related to the chassis hull was verified by strength calculations using FEM (finite element method) techniques.

The PT-91 M chassis with installed components of the bridgelayer: main arm actuator, main arm, rear support arm, is shown in Fig. 8.

4.4. Power hydraulics

A diagram of the hydraulic system of the PMC-LEGUAN bridge is shown in Fig. 6.

Due to the lack of room in the chassis, a decision was taken to power the hydraulic system pump drive from the power-pack using the PTO (power take off). A special speed reduction system was designed to deal with the large difference between the PTO shaft speed and the required speed of the pump drive shaft. This construction unit, shown schematically in Fig. 7, includes, among others: Cardan shaft, electromagnetic clutch, reduction gear and pump drive control system (switching on and off).

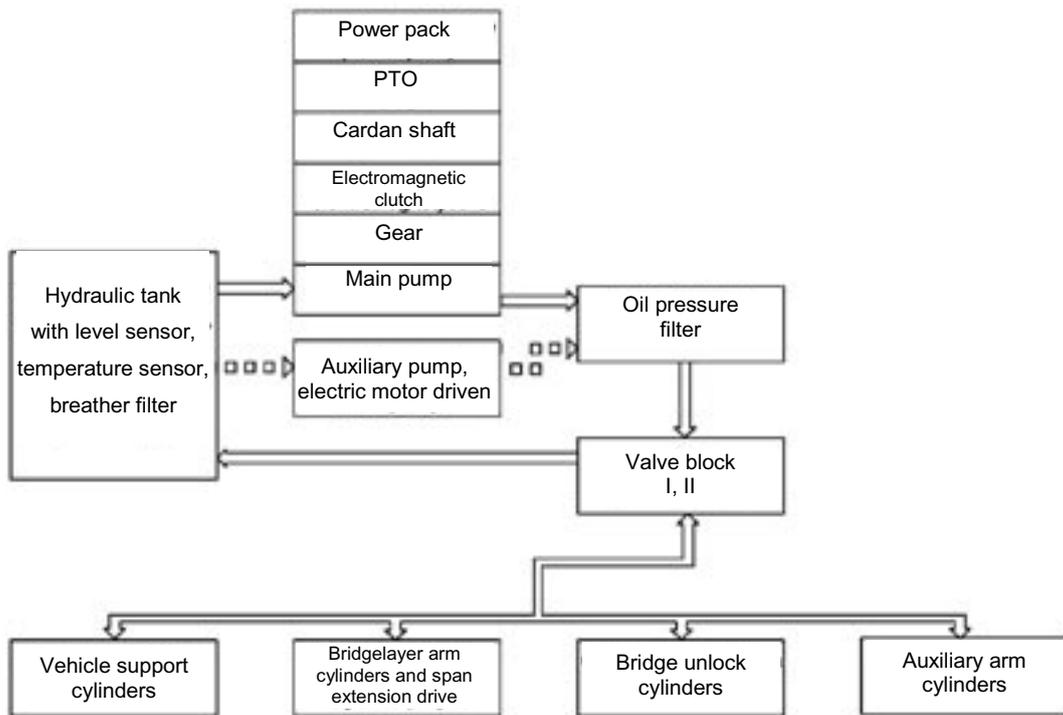


Fig. 6. Block diagram of the bridge's power hydraulics [9]



Fig. 7. Drive of hydraulic system pump - block diagram

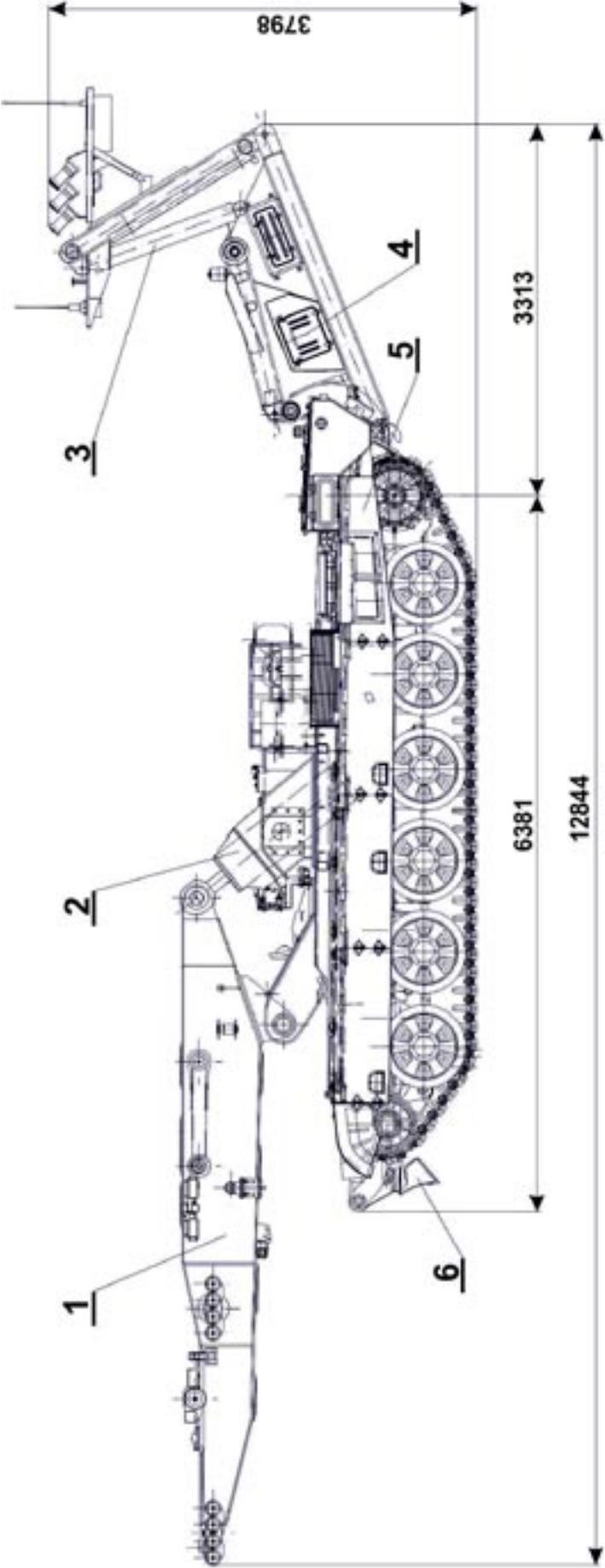


Fig. 8. Chassis with bridgelay components

1 – front arm of bridgelay, 2 – main actuator, 3 – rear arm of bridgelay, 4 – equipment, 5 – chassis body, 6 – bank support.

4.5. Span launch and retrieval control system [9]

The scope of deliveries from MAN also included a system for controlling the launching and retrieval of the bridge span along with the necessary sensors and actuators. The system was consolidated with the existing control and power systems of the PT-91M tank chassis. The principal element that determines user-friendliness is the multi-function display - control panel with function keys. The control panel is shown in Fig. 9.

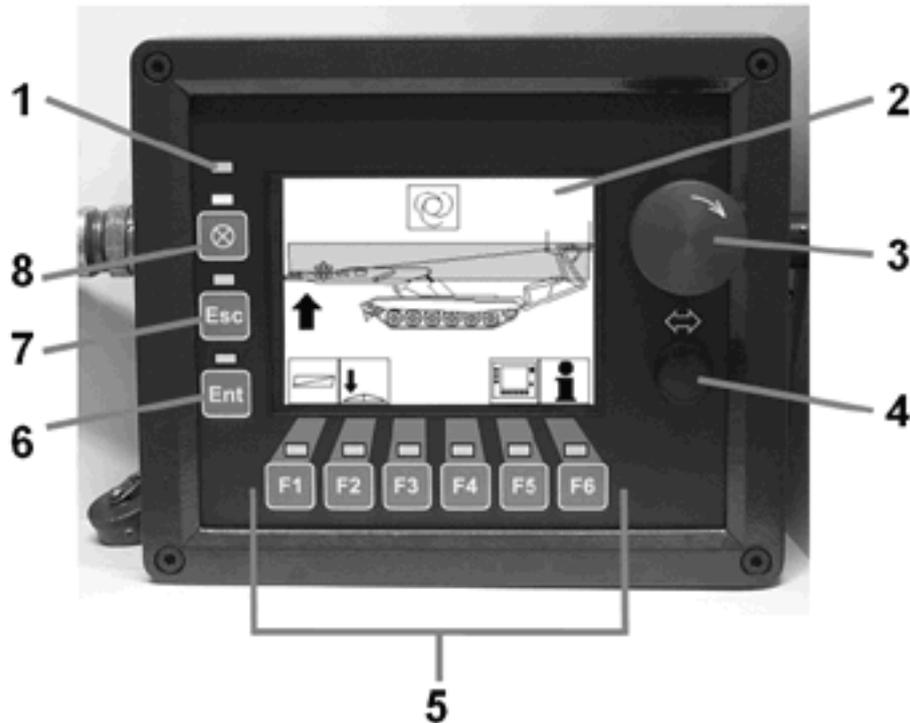


Fig. 9. Operating panel

- | | |
|---------------------------|--------------------------|
| 1 - Brightness sensor | 2 - Display |
| 3 - Emergency off switch | 4 - Adjustment regulator |
| 5 - Function keys (F1-F6) | 6 - Delete key (Ent) |
| 7 - Esc key | 8 - Brightness key |

The operating panel integrates a colour display whose graphical user interface allows the operator to select various operating modes and view various information menus. The interface also has maintenance menus that allow for the modification of certain parameters.

4.5.1. Function keys

Operator inputs are realized via the six function keys (F1-F6), the Esc key, the Delete key and the adjustment regulator.

4.5.2. Function keys F1-F6

Each function key carries out a specific function, which is indicated by the symbol directly above the key. The absence of such a symbol indicates either that the key has not been assigned a function or that it has been deactivated.

4.5.3. Delete key (Ent)

This key allows the operator to end a manual action, an operating mode, a series of steps or the like, or to navigate to a menu that has been selected in order to carry out an action such as selecting a drive unit in manual operating mode.

4.5.4. Esc key

Pressing the Esc key reverts to the previous menu.

4.5.5. Adjustment regulator

To adjust screen brightness, the brightness key should be held down while pressing the adjustment regulator.

4.5.6. Emergency off key

Pressing the emergency off key on the operating panel shuts down the output modules for the valve regulation system.

In such a case the control system and the operating panel remain activated and an error analysis can then be carried out via the operating panel.

4.5.7. Operation and use of the operating panel

The following functions are available via a menu-controlled user interface that is integrated into the operating panel for the launching mechanism:

- operation of the launching mechanism;
- status of all components;
- system monitoring for error detection purposes;
- support for error elimination, as well as for servicing.

The bridge launching mechanism is to be operated **solely** using the integrated operating panel.

The various phases of the bridge launching and retrieval procedure are indicated via graphics in the upper display line on the screen. This allows monitoring the procedure via the operating panel and making any adjustments that may be necessary. The position values and component statuses of the various drive units are also displayed.

The bridge launching mechanism can be switched to manual or emergency operating mode under difficult terrain conditions in the event of a drive unit error or if a drive unit is in the wrong position.

4.5.8. Information menu

In the information menu, the following types of information regarding the various components can be viewed:

- status and absolute position of the hydraulic drive units;
- drive unit and valve proximity switches;

- fuses, valve blocks;
- pumps, hydraulic system;
- statuses of software elements such as the operating-time meter and the version status of the process-control computer software and hardware

4.6. Consolidation of the units and assemblies of the bridge

The work carried out at OBRUM required close cooperation with the designers of the PT-91 M MBT chassis. Redesign of the middle part of the body allowed to retain the optimum position of the main cylinder and of the bridgelayer, ensuring thereby proper operation of the bridge. The requirement to maintain the stability of the structure forced the design engineers at Bumar-Łabędy S.A. to repeatedly redesign the manner and location of installing additional equipment, including with the use of the rear support arm of the bridgelayer.

The studies and calculations made and multi-variant concepts (design of the installation of bridge spans and bridgelayer on the chassis) developed by OBRUM's engineers finally led to the necessary changes in the deliveries from cooperating parties and to weight reduction of the bridge spans. This problem was one of the most difficult due to the supply from current production. MAN Technologie AG strived to avoid making any changes in the proven design. Eventually they redesigned the bridge spans and reduced its weight, which resulted in scaling down its classification from 70 MLC to 60 MLC (Table 1).

A complete Polish PMC - LEGUAN bridge is shown during testing and trials in Fig. 10.



Fig. 10. PMC – LEGUAN assault bridge (PT-91M chassis with six pairs of road wheels)

5. SUMMARY

Modern military bridges are required to have high load capacity and mobility of use, while ensuring a high level of automation and mechanization of all work related to their deployment and dismantling. Therefore, modern solutions from the field of electronics, hydraulics and control technology are used in their design, and the structure itself is built of modern materials of adequate strength and low weight. In addition, such assemblies include tools and devices for assembly, diagnostics and protection of crossings as well as modern systems used for simulation and training purposes or to develop effective methodology of use in future combat and other tasks.

The developed version of the PMC- LEGUAN assault bridge, which comprises the consolidated chassis of the PT- 91 M MBT with extendable LEGUAN bridge spans, is an interesting design of a tracked transportable bridge. The bridge launching and retrieval automation technologies of MAN Technologie AG, including visualization of the individual process stages on a display, monitoring of the status of actuators and sensors are operator-friendly and improve the operational safety and minimize accidental damage resulting from operating errors. The operating panel constitutes a modern Human Machine Interface (HMI) and has innovative features in the control of bridge launching and retrieval in comparison to other manufacturers of transportable bridges.

The Malaysian client has set high technical and performance requirements and imposed a multi-stage mode of control and acceptance processes. The manufactured bridges passed tests and trials that were carried out in the presence and with the participation of Malaysian officers. Tests were performed both in Poland and in Malaysia. PMC - LEGUAN assault bridges delivered under the contract have passed all acceptance tests and are used by the Malaysian army - Land Forces of the Kingdom of Malaysia.

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