APPLICATION OF A SELECTED TRANSFORMED ENGINE FROM REDUNDANT SPECIAL EQUIPMENT FOR CRISIS MANAGEMENT NEEDS

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Abstract

The article performed an analysis of possibilities of the conversion of military helicopter turbo shaft engines for energetic use. The possibilities of the transformation of the turbo shaft engine on the energetic unit are indicated on the example of the helicopter turbo shaft engine GTD-350, which was used in the military version of the Mi-2 helicopters. The article is the result of detailed studies, which creates the basic prerequisites for solving the problems in industrial conditions.

Keywords: special technique, transformed aero turbo shaft engine, power unit, crisis management.

1 Introduction

The Slovak Republic Armed Forces Air Force (VS OS SR) has undergone several reforms since their establishment in 1993 year, resulting in a significant reduction of flying and technical personnel and in a substantial reduction in numbers of military aviation equipment and material. In a period of their establishment the VS OS SR were equipped with 146 aircraft. Nowadays the VS OS SR are equipped with 44 aircraft (12 MiG-29A supersonic combat aircraft and MiG-29UB, 10 pieces of L-39 training turbo-jet planes, 9 pcs of transport aircraft (2 pcs of An-26 and 7 pcs of L-410) and 13 helicopters (12 pcs of Mi-17 and 1 pc of Mi-2). For the last twenty years a great amount of redundant special equipment have been inactivated in addition to a great number of aviation equipment. Transformation of such highly sophisticated and specialized military equipment for an alternative application is very topical at the present time [1]. As an example of such application of military aviation equipment is a project of a transformation of the GTD-350 inactivated redundant turbo shaft helicopter engine from inactivated Mi-2 military helicopters for a small mobile general-purpose power source suitable for using in crisis management conditions.

The article represents an initial study aiming to suggest possible approaches in a transformation of the redundant special equipment for an alternative application.

2 Analysis of a transformation applicability of available aviation turboprop engines for a power unit for ground applications

The turbo-propelled aviation turboprop aviation engines (TvLTKM) and the helicopter turbo shaft engines (ThLTKM) have the greatest potential for a transformation of aviation turboprop engines for an alternative application, whose power of the output shaft can be transferred either directly or through a reducer to a driven unit. Such engines after having been transformed can be used for propulsion of an electric generator as a back-up or an emergency power source for a power drive of air-pumps or pumps in solving crisis situations after disasters or in electric energy blackouts etc. TvLTKMs and helicopter ThLTKM, being available from inactivated military airborne vehicles (An-24, An-26 and L-410) and helicopters (Mi-2, Mi-8 and Mi-24D, Mi-24V, Mi-24DU) on the territory of the Slovak Republic provide a wide range of outputs on a output shaft from 294,4 kW up to 2075 kW with a weight from 139 kg up to 600 kg [2].

The basic parameters of the TvLTKM and ThLTKM, which are available on the territory of the Slovak Republic, are shown in the Table 1.

AI-24 single-shaft turbo shaft engines of the 2nd series had been providing the power drive for An-24 medium transport aircraft of the VS OS SR until a tragic crash at the Hejce Hungarian village, after which the An-24 aircraft were put out of service. A more powerful version of AI-24VT turbo-propelled engines provides power drive for An-26 transport aircraft, whose operation within the VS OS SR stops when a technical life will be finished. There are 6 pcs of such engines available.

Double-shaft M-601 turbo-propelled engines in various versions (M-601A, M-601B, M-601D, M-601E, M-601F, M-601H-80) are used for power drive of small L-410 transport aircraft in various versions (L-410A, L-410FG, L-410UVP, L-410T and L-420).These turbo shaft engines have been produced in large series (more than 1000 pcs) and their production and development (M-601H-80) go on at present time. A special version of the

M-601Z engine provides power drive for the Z-37T agriculture aircraft, being used in agriculture [3]. Most of M-601 engines of various versions after having finished their technical life are sent for overhaul in the Czech Republic, so a number of available engines are minimal.

Table 1 *Basic parameters of the TvLTKM and ThLTKM used by the VS OS SR *[1]*

Ser.	Engine type	P [kW]	G [kg]	L [mm]	W/V [mm]	$n_{VT,max.}$ [$min.^{-1}$]	$n_{TK,max.}$ [$min.^{-1}$]	c_m [$kg.W^{-1}.h^{-1}$]	Remark
1.	AI-24, 2nd series	1887	600	2346	677/1075	15800	-	0,324	TvLTKM
2.	AI-24VT	2103	600	2346	677/1075	15800	-	0,256	TvLTKM
3.	M-601	559	187	1675	592/600	36660	31023	0,368	TvLTKM
4.	TV2-117A	1104	330	2835	547/745	21200	12000	0,4	ThLTKM
5.	TV3-117	1636	285	2055	650/728	19500	15000	0,313	ThLTKM
6.	GTD-350	294,4	139	1385	626/760	45000	24000	0,486	ThLTKM

The TV-2-117A turbo shaft engine is used for Mi-8 helicopters power drive in various versions. The TV2-117A engine has been used in the Slovak Republic within the VS OS SR and by the units of the Ministry of Interior. At present time it is used by commercial aviation companies performing air services with minimum numbers. The redundant TV2-117 engines are not available.

The TV3-117 turbo shaft engine in various versions (TV3-117, the 3rd series, TV3-117MT, TV3-117V) is the most widespread type of a turbo shaft engine, which was used within the VS OS SR in the Mi-24, Mi-24D and Mi-24DU helicopters and in Mi-17. Nowadays only the version of the TV3-117MT engine is used in Mi-17 helicopters. The helicopters ThLTKM TV3-117 in different versions are nowadays very demanded on the worldwide market and they are not available in sufficient amount in the Slovakia.

Light Mi-2 helicopters were largely represented within the VS OS SR and they were driven by two GTD-350 turbo shaft engines. The advantage of this engine is that its design includes a reducer as well, reducing high operating speed of a free gas turbine to an acceptable value for different technical equipment. Due to the inactivation of all, except for one Mi-2 helicopter, which has been used for training purposes, there is a relatively large stockpile of the ThLTKM of this type in Slovakia. The ThLTKM GTD-350 had been produced for long years with license in Poland, where they are repaired despite the termination of their mass production and a stock of spare parts is available [4].

Based on a performed analysis of TvLTKMs and ThLTKMs available in range of the VS OS SR and in civil aviation it is obvious, that the most available type of the LTKM, which is suitable for a transformation for power equipment for crisis management is the ThLTKM GTD-350. Its advantage is a number of available engines, which are redundant, as well as a suitable power range of the engine.

3 Analysis of design features of the GTD-350 turbo shaft engine

This turbo shaft engine was designed in 1958-1961 by the Soviet bureau headed by Sergei P Izotov to power the Mi-2 helicopter. In 1963 this helicopter was assigned for production to Poland's WSK-PZL Swidnik, and this factory delivered 5,418 in 112 batches, completed in 1998. The engine GTD-350 was mass-produced by WSK PZL (Rzeszow, Poland) till the end of the 90s. This Polish factory delivered over 19,000 engines from 1966. The total number of hours in operation for these engines exceeds 20 million.

The design of the engine GTD-350 is similar like the Allison Model 250 engine, now known as the Rolls-Royce M250, (US military designations T63 and T703) is a highly successful turbo shaft engine family, originally developed by the Allison Engine Company in the early 1960s. The Model 250 has been produced by Rolls-Royce since it acquired Allison in 1995.

In the Table 2 there are shown the basic parameters of the GTD-350 engine from the first up to the fourth production series. From the given table it is obvious, that the most suitable operating mode for a transformed engine is a regime corresponding to the I. and II cruising regimes, when a thermal and mechanical load of the engine is optimal and an operation time is unlimited. An input part of the GTD-350 engine is formed by an outer and an inner covers, which are connected with nine hollow aero dynamical fins. The aero dynamical fins and an input aero dynamical lid are warmed-up with hot air, which is drawn from the eighth stage of the compressor and it is directed through a double cover into the hollow fins and into an inner room of an aerodynamic lid.

*[1] P – power; G – dead weight; L – length; W – width; V –; $n_{VT,max.}$ – maximum rounds of a free gas turbine; $n_{TK,max.}$ – maximum rounds of a turbo-compressor; c_m – specific fuel consumption.

Table 2 *Regimes of the GTD-350 engine*

PARAMETER / REGIME	Engine series	Output on a shaft P [kW]	Rounds of turbo compressor rotor n_{TK} [%]	Rounds of a free gas turbine n_{VT} [%]	Gas temperature before turbine t_{3c} [°C]	Specific consumption of fuel c_m [kg.kW^{-1}.h^{-1}]	Operation time τ [min.]
FLIGHT (at MŠA)	I.	294,4	96	97±1	955	0,4964	6´ (5 % of a technical life)
	II.	294,4	96	97±1	955	0,4964	
	III. and IV.	294,4	96	97±1	940	0,4964	
FLIGHT (T_H = 40°C, P_H = 760 mm Hg)	I.	257,6	-	-	985	-	6´ (5 % of a technical life)
	II.	257,6	-	-	985	-	
	III. and IV.	257,6	-	-	970	-	
NOMINAL	I.	235,52	90	101±1	890	0,5304	60´ (60 % of a technical life)
	II.	235,52	90	101±1	870	0,5304	
	III. and IV.	235,52	90	101±1	860	0,5304	
I. CRUISING	I.	209,76	87,5	max. 104	860	0,5576	unlimited
	II.	209,76	87,5	max. 104	840	0,5576	
	III. and IV.	209,76	87,5	max. 104	840	0,5576	
II. CRUISING	I.	172,96	84,5	max. 104	825	0,6045	unlimited
	II.	172,96	84,5	max. 104	800	0,6045	
	III. and IV.	172,96	84,5	max.104	800	0,6045	
IDLE	I.	-	57±3	62±12	790	Fuel consumption per hour 55 kg.h^{-1}	20´
	II.	-	57±3	62±12	790		
	III. and IV.	-	57±3	62±12	790		

The compressor of the GTD-350 engine is a single-flow, single-shaft, axially-radial one, formed by seven axial stages and a radial stage. An increase of a resource of a stable operation of the compressor is provided by an air relief valve after the sixth stage of the compressor. The compressor body is an essential power element of the engine. An input part of the compressor is fixed to the frontal flange. A diffuser body of the radial compressor is fixed to the rear flange of the body of the compressor radial stage.

A combustion chamber of the GTD-350 engine is a countercurrent one, tube-type with a single flame tube and two tube-type air supplies from the engine compressor. The combustion chamber is formed by a combustion chamber body with a diffuser, a flame tube, a fuel nozzle, an igniter and two tubes of air supply from the compressor. The combustion chamber body has a spherical base with a welded diffuser and two air intakes. On the body there is a flange for a fuel nozzle and a flange to fix a combustion chamber igniter to.

A gas turbine of the compressor of the GTD-350 engine provides the compressor and engine aggregates located on a frontal body of the reducer with a power drive. It is axial, simple-stage, high-speed one with un-cooled blades of a reaction type. A stator of the compressor gas turbine is connected with an outer cover of the combustion chamber. The stator is formed by a rectifying mechanism of a compressor gas turbine, by a frontal body, a rear body and a lid. Cooling air is supplied from a combustion chamber of the engine aiming to cool down the parts of the compressor gas turbine. The rotor of a compressor gas turbine is located on a frontal cylindrical bearing Nr. 6 and on the rear ball bearing Nr.3.

A free gas turbine provides the main reducer with power drive through the engine reducer. It is radial one, two-stage, high-speed, with uncooled blades of reactive type. A free gas turbine of the engine is formed by a rectifying mechanism of the first stage, a rectifying mechanism of the second stage, a two-stage rotor of the free gas turbine and two supports. The stator parts of both stages of a free gas turbine are formed by a welded un-demountable unit, which is a power part of the engine. The rotor of a free gas turbine is located on a cylindrical bearing Nr. 5 and on a ball bearing Nr. 4. Both bearings are fixed to the body of the gas collector. A rotor shaft of a free gas turbine is connected through a gear transmission to an engine reducer.

An output mechanism of the GTD-350 engine provides the gas exhausting from the engine to atmosphere. The output mechanism is composed of a gas collector, output tubes and lids. The gas collector is a part of a power part of an engine. A body of the gas collector provides a transmission of forces from the rotor bearings of a free gas turbine to the body of gas turbines, to the body of a combustion chamber and to the body of the engine reducer. The body of the gas collector interlinks a body of gas turbines with a body of the engine reducer. Two output tubes providing gas exhausting from the gas collector out of the engine are attached to the body of the gas collector so that gas flows make 90° position.

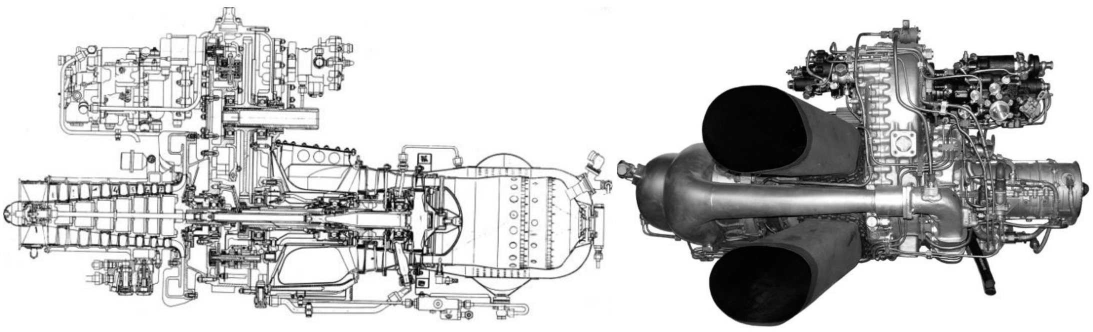


Fig. 1 *GTD-350 turbo shaft helicopter engine*

The reducer of the GTD-350 engine provides a speed reduction and a transmission of torque from the shaft of a free gas turbine to the output shaft of the reducer, from which the torque is transmitted to the main reducer of the helicopter. Engine reducer is composed of a frontal gear-wheel system, reducing a speed for particular units located on the engine reducer. The bearings and reducer gear-wheels of the reducer are lubricated and cooled with oil from an oil system of the engine. On the body of the engine reducer there is the NR-40TA pump-regulator attached through the use of flange, a centrifugal air-purger, and speed regulator of a free RO-40TA gas turbine, a speed indicator of a free gas turbine, a block of oil pumps, STG-3 starter-generator and a speed indicator of a turbo-compressor. A centrifugal air purger, speed regulator of a free gas turbine and a speed indicator of a free gas turbine are powered from a rotor of a free gas turbine, the other mechanisms are powered by a torque from a gas turbine of the compressor.

The oil system of the GTD-350 engine is a pressure one, closed, of a circulating type with direct air exhaustion to atmosphere. It is composed of an oil tank, a block of oil pumps, oil cleaner with a unidirectional and transforming, centrifugal separator and an oil heater. An oil tank and an oil heater are placed on the helicopter hull. Operating pressure of the oil in a pressure line is p_o = 0,15 up to $0{,}3^{+0{,}05}$ MPa. Air exhaustion of the oil tank and other parts of the oil system is delivered to the engine reducer, from which the air is taken out to atmosphere through a centrifugal air purger. “B-3V” synthetic oil is used in the engine oil system.

The fuel regulation system of the GTD-350 engine provides for sustainment of permanent speed of a free gas turbine and sustainment of a stable operation of the engine in all preset regimes through adjustment of fuel supply by the NR-40TA pump-regulator into a combustion chamber. The fuel system of the engine consists of the NR-40TA pump-regulator, an RO-40TA speed regulator, DS-40T signal transmitter, a SO-40 power synchronizer, an initiating electromagnetic valve with a permanent pressure valve, an igniter with an initiating fuel nozzle and a sparking plug, a fuel nozzle, air relief valve, defrosting system valve, and a block of exhausting valves.

Exhausting mechanism of the GTD-350 engine provides releasing of exhaust from a fuel nozzle, from a cover of the combustion chamber and from an igniter fuel nozzle to the waste tank of the helicopter. Release of the waste fuel is implemented through a block of exhausting valves, which is controlled by a fuel pressure from the fuel regulation system of the engine.

Defrosting mechanism of the GTD-350 engine provides a protection of an input mechanism of the engine compressor and an aerodynamic hat against a frost cover. In a defrosting mechanism there is used a hot air, taken from the space of the last stage of the engine compressor.

An initiating mechanism of the GTD-350 engine provides an activation of the engine on the ground and in flight. An initiating mechanism of the engine is automatic, independent, controlled with the PSG-14A initiating board. An engine initiation system and a power supply is formed by a STG-3 starter-generator, a PSG-14A initiating board, two pcs of 12 SAM-28 accumulator batteries, two battery switch contactors, a notch coil starter-generator relay, starter-generator armature contactors, a RN-120U voltage controller, AZP-8M safeguard machine, a locking relay and a safeguard relay. Engine cranking in starting is provided by the STG-3 starter-generator operating in starting mode. In operation the GTD-350 engine works in a generator regime and it provides for direct current supply to the helicopter board network. The starter-generator is designed as a direct current generator with a separate excitation. An ignition of the fuel and air mixture is ensured by the SKND-11-1A igniting mechanism through the SP-18UA sparking plug in a combustion chamber.

Control system of the fuel units enables a visual control of the operation of GTD-350 engines by dial markers indicating speed of rotor of a free gas turbine n_{NR}, indication of the speed of the turbo-compressor rotor n_{TK}, indication of the gas temperature before a compressor gas turbine t_{3c} and indication of the oil pressure p_o [5].

4 Possibilities of the application of a supposed power unit for crisis management

The helicopter ThLTKM GTD-350 engine with an available power ranging from 172 up to 235 kW can be used for various purposes after its transformation. On internet and in a special literature there are published successful trials on use of the GTD-350 engine for alternative purposes (motorboat power drive, car power drive etc.) [6]. In this part there are analyzed particular possibilities of using a transformed GTD-350 turbo-shaft engine for energetic purposes.

4.1 A ground source for aircraft actuation

A designed container is equipped with a chassis for an operation on permanent airports, eventually on temporary air fields. The proposal assumes using of output power of the engine in an original form or an adjustment of the output power (using voltage changers) in accordance with requirements for a particular type of actuated aviation equipment. A ground source can be applied by companies, performing aviation works on airports with a weak infrastructure, in military air force etc.

4.2 A back-up unit for powering electrical power networks

A container in a stationary version is assigned to power important parts of electric power networks in case of blackouts of primary power supply. A source of electric energy can be a starter-generator (use of convertor is a must) or a generator driven from an output shaft of the engine reducer (a gearing mechanism is needed). Application for power supplying of energy networks as computer networks, security systems, emergency lighting, air-conditioning and cooling systems, etc. Possible application in computer and information centers, organizations equipped with laboratories and in development institutions, hospitals, works and premises etc.

4.3 Power unit to be used in building and repairing in the field

A container in a stationary version or in a mobile version equipped with a chassis is assigned to provide a power supply with electric energy to perform repairs and works in the field. Its application is in providing power supplying for mobile works (machine-tools, welding equipment, illumination etc.), in repairs and building in places without infrastructure, etc. Its application is possible in construction companies, mines and quarries, in timber production etc.

4.4 Power unit to be used in armed forces and in crisis management

A container in a stationary version or in a mobile version equipped with a chassis is assigned for a production of electric energy to ensure an operation of security component in the field. The application is possible in field hospitals, in Air Defence components, at command and communication posts, for needs of radiolocation and radio-communication means, for engineer units, field repair works etc. The equipment is applicable for needs of crisis management, for fire-fighters, rescue components and units of the civil protection and in rescuing citizens at disasters, industrial accidents and other emergency incidents.

4.5 Experimental equipment for research

A container in a stationary version is applicable for universities, research organizations and laboratories performing research in area of thermodynamics, small jet engines, power sources, renewable resources of energy etc. Such equipment might be a very interesting alternative to new equipment being delivered by a manufacturer from a point of financial costs. A price of new equipment is several times higher than a supposed price of the proposed equipment. The equipment can be modified in accordance with a focus on a planned research of a particular university or a research institute.

5 Design of the GTD-350 helicopter engine for power units

In designing the transformation of a GTD-3 turbo-shaft helicopter engine for an energy installation for ground application some basic requirements have been stated:

- Exploitability of the equipment,
- Simplicity of a designed transformation,
- Low costs of transformation,
- Simplicity of servicing and maintenance of the equipment,
- Independence of the equipment,
- Simplicity of the transportation of the equipment and its storage,
- Operational safety,
- Meeting of environmental and legislative requirements.

Transformation design is aiming to reach a minimum actual price of the equipment with minimum intervention into the construction of an original engine and its system with maximum possibility of using operable parts and machine sets from decommissioned Mi-2 helicopters, in which the GTD-350 had been applied. The other parts of a proposed construction of the equipment are tested and they are readily available on the market. The focus is laid on a manufacturing simplicity. By meeting these requirements a minimization of costs is reached in designing the energy equipment.

Designed equipment should be simple in usage, servicing and maintenance in day and night conditions. The engine and its systems and machine sets of all equipment should be easy to handle, control, well accessible for servicing and maintenance, eventually easily dismountable and interchangeable. Operating and controlling elements and devices should be easily accessible, integrated in an operating board, systematically and logically arranged. Attention should be mainly paid to a possible immediate emergency shutoff.

The power equipment must be independent; it means a requirement of a zero dependence of the equipment from other necessary devices, appliances, materials. A designed container for power equipment should contain all necessary accessories needed for a reliable operation of the equipment for a supposed period. It includes sufficient supplies of operational liquids, basic necessary instruments and tools needed for maintenance of the engine and whole equipment, eventually necessary appliances or other necessary instrumentation.

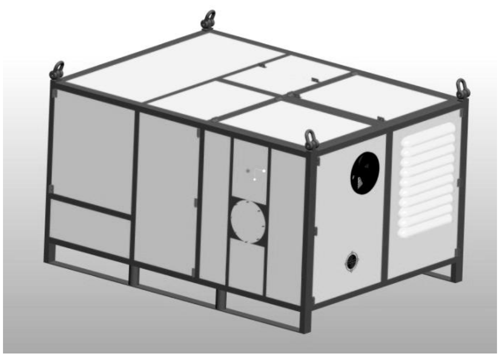
Meeting of requirements for transportation of designed equipment is very important. The equipment should be transportable with common transport means (automobile means, trail cars, helicopters, aircraft, boats etc.). In this regard the proposed outer dimensions, weight, possible anchoring and fixation of the equipment are very important. An easy equipment handling with common available means must be ensured (lift trucks handling trucks, hydraulic boom, cranes, etc.). A mobile version with a chassis has to meet in full range the approval requirements for operation on land communications (dimensions, illumination etc.). Attention should be focused on the issue of the equipment protection in transportation and storage, eventually in a longer layoff and storage in covered and unshielded rooms.

An extremely important requirement, which is laid on the equipment, is safety of its operation. Designed equipment will contain potentially dangerous elements, including: high-speed engine, large volume of combustible liquids, electric equipment alive, hot gases piping and others. A very important issue is a solution of the fire-safety of the equipment. It requires using of passive and active elements of fire protection. The proposal supposes a separation of an engine room from other parts of the equipment with fireproof walls. Active elements of fire protection should include a fire fighting system of the equipment as well as an easily accessible fire-extinguisher able to extinguish not only solid and liquid inflammables, but also alive electric equipment. Stocks of available fire extinguishing agents should be sufficient to defeat a possible fire. It is needed to take into consideration also other implications concerning safety related with a protection against injury caused by electric current, electric burn, possible leakage of oil products, potential risks related with exhaust gases (contamination of a bounded space), etc.

Nowadays the requirements from the area of environment protection play a significant role. Meeting of valid standards for noise and emission levels are up-to-date for the proposed equipment. With regard to a particular application there exist requirements regarding maximum authorized level of noise in operation of the equipment. In designing an output engine system a design of a noise silencer needs to be taken into consideration. In designing a container it will be necessary to use suitable facing materials, enabling absorption of noise and vibrations. Additional environmental problem, which must be taken into consideration, is meeting legislative requirements from a point of emission levels. In addition to the mentioned problems, it is necessary to solve an issue of an environmental protection against leakage of oil products contained in the equipment.

Proposal of the transformation of the GTD-350 turbo-shaft helicopter engine for a power unit represents an initial study, which will require a detailed development in a practical implementation.

Fig.2 *The container in a transportation configuration*



The power equipment is proposed as a compact unit placed on a stationary or a mobile container with standard dimensions. The container enables placing of all structural parts and systems of the power equipment which are independent from an outer infrastructure during their operation. The container having been already designed can be taken into consideration in a detailed designing of the AI-9V transformed small jet engine to a general-purpose power unit [7]. With regard to unequal dimensions of the GTD-350 turbo-shaft engine and the AI-9V air generator, it will be necessary to change an arrangement of inner spaces and to change fuel supplies in a fuel tank.

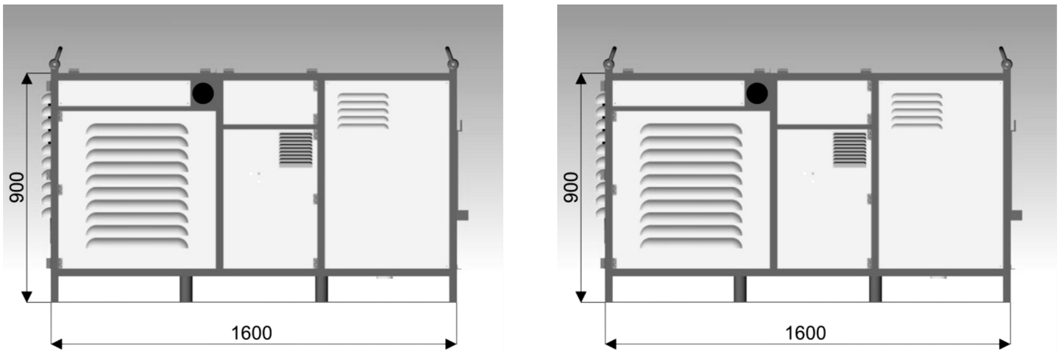


Fig. 3 *Suggested container dimensions*

6 Conclusion

The analyses of transformation of a chosen type of a turbo-shaft helicopter engine enables using of redundant special equipment, being stored in storehouses for needs of crisis management. The available output of the GTD-350 turbo-shaft helicopter engine enables, after having been transformed, the energy supplying for needs of various technical mechanisms used in crisis situations. Mobility of proposed equipment and a swift commissioning of the proposed power equipment increase its applicability in crisis management conditions. With regard to the fact that a redundant material is used, the initial economic costs are reduced in designing the power equipment. Availability of the GTD-350 engines enables an implementation of their transformation in larger amounts.

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