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Security of bottle to fill in a high pressure air

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Abstract: Charging the bottle of high pressure air isolation devices is performed by a high-pressure compressor. The charging time is in function of the compressor capacity and the intensity of the nominal pressure of the air in the bottle. However, in accident situations this time is long and therefore high-pressure accumulators are used where the filling time of the bottle of isolation apparatus has been drastically reduced. Due to the short filling time of the bottle through the air flow, there is a thermodynamic load of bottle material that could endanger the safety of users and other participants in the area. It is therefore *necessary to determine the critical parameters of the rapid charge and their intensity.*

1. Introduction

In fire-fighting interventions, firefighters use isolation apparatus for personal protection of the respiratory system. One of the essential modules of the insulating device is a tank (tank-bottle) so-called. medical air. When the reservoir is full, the pressure in it is 30 MPa, and during the use of the insulation device, this pressure decreases in the user's load function. Consumption of air ranges from 10 l / min to 100 l / min. in the function of airflow, ie. user load. Filling the bottle with medical air is most often done by high pressure compressors [1]. The charging time is in the function of the air flow (compressor capacity) and the nominal pressure, this charging in practice of a bottle of 6,8 l usually takes from 10 to 15 minutes. In accidents, time is a very important factor, because it is easier to overcome the fire when the zone where it came down is smaller, so the bottling time is very long. The user at the maximum load can intervene for 20 to 25 minutes and afterwards must withdraw from the accident zone in order to replace the bottle of air or its recharging with medical air. In order to overcome these problems i.e. shortening the charging time, charging is performed from the medical air accumulator (air banks). The battery usually has a volume of 100 dm3 to 300 dm3. The time to fill the bottle of insulation devices is about 1 minutes if it is charged from the medical air accumulator. In doing so, it is not necessary to dismount a bottle from the insulator carrier and remove the insulating device from the back of the user. So, the time to re-fire the fire is shortened. However, the question arises as to how quickly it is possible to quickly fill the bottle without the need for a new accidents during the existing one. Rapidly increasing the pressure in the bottle leads to a rapid change in the stress state in the bottle material. The voltage states are mechanical and thermal. Due to the flow of air through the valve of the bottle, there is the appearance of heat that causes temperature stresses in the bottle material. These temperature stresses are not evenly distributed, i.e. they appear in certain local places.

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2. Filing time of the bottle

Bottles of insulating devices are made of steel, semi-composite and composite materials, Figures 1 and 2. The bottle material has no effect on the rate of its loading, but it has a schedule and intensity of stress conditions in the wall of the bottle. Also, the charging rate affects the arrangement and intensity of the strain-deformation state in the bottle material. Therefore, account must be taken, in particular for semi-composite and composite bottles, of possible damaged walls that can cause an accidental situation with severe consequences for the user and other participants in the bottling zone of the bottle with medical air. Due to the above mentioned research problems, they are focused on the rate of increase of pressure over time.

Figure 1. Bottles for compressed medical, steel material

Figure 2. Bottles for compressed medical, composite material

The amount of air in the bottle can be calculated over the equation

$$V_1 = V_o \frac{P_1}{p_o} \tag{1}$$

where is:

V_1- the quantity of air in the bottle, m^3
V_2 - bottle volume, m^3
P_1 - end pressure in the bottle, MPa
P_O- initial pressure in the bottle, MPa.

The mean value of the airflow volume when the bottle is filled, if the high pressure compressor charge is calculated according to the equation

$$Q = \frac{V_1}{t} \tag{2}$$

where is:

V_1- the quantity of air in the bottle, m3
Q - amount of flow in unit time, m3 / min
t - the time for which the pressure in the bottle increased to the desired (required, nominal) pressure, min.

2.1. Filling the bottle with a multistage compressor

The bottling time of the bottle in a standard way, i.e. compressors with high pressure, is in function of the volume of the bottle, the nominal pressure in the bottle and the capacity of the compressor. The nominal compressor flow in the experimental research is 250 lit./min. Table 1 shows the values of the pressure increase and the amount of air in the bottle in the function of time.

Table 1. Increase of pressure and quantity of air in the function of time-steel bottle

Time sec.	Pressure (MPa)	Quantity of air m3	Quantity of air l
0	0	0	0
60	0,2	0.012	120
120	3	0.18	180
180	7.7	0.462	462
240	11.2	0.672	672
300	15	0.9	900
360	18,6	1.116	1116
420	22.15	1.329	1329
480	25.9	1.554	1554
540	29.2	1.752	1752
600	32.7	1.962	1962

Table 2. Increase of pressure and amount of air in function of time-composite bottle

Time sec.	Pressure (MPa)	Quantity of air m3	Quantity of air l
0	0	0	0
60	0,2	0.010	100
120	4	0.272	272
180	7.2	0.4896	489
240	10.6	0.72	720
300	13.8	0.93	930
360	16.9	1.149	1140
420	19.9	1.353	1353
480	223.2	1.577	1577
540	26.2	1.781	1781
600	29.3	1.992	1992
660	32.3	2.196	2196

The real increase in air volume is about 0.210 m3 / minute, while the rated flow of the compressor is 0.25 m3 / min. The charging time of the 6 liter bottle is 10 minutes. The dependence of the increase in air pressure in the function of time is given in Figure 3.

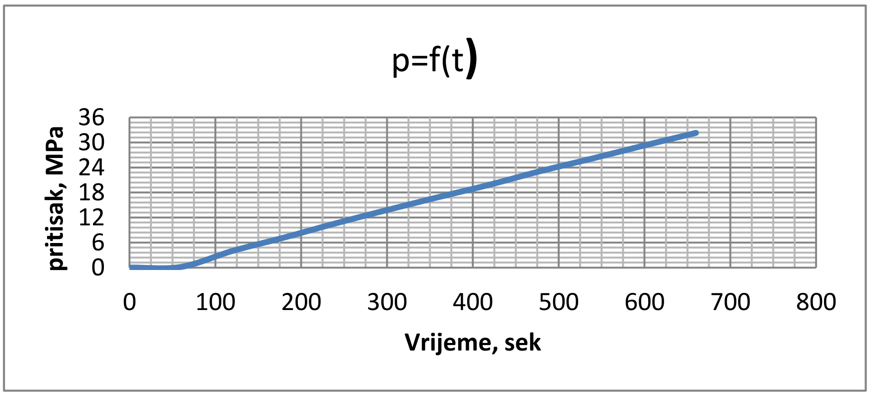

Figure 3. Pressure boost in function of time

IOP Conf. Series: Materials Science and Engineering **294** (2018) 012085 doi:10.1088/1757-899X/294/1/012085

When air flows due to air flow and friction, there is a rise in temperature in the segments of the bottle [1-4]. The recording was performed using a thermocouple, Figures 4, 5 and 6.

Figure 4. Temperature intensity at valve, comp. bottle

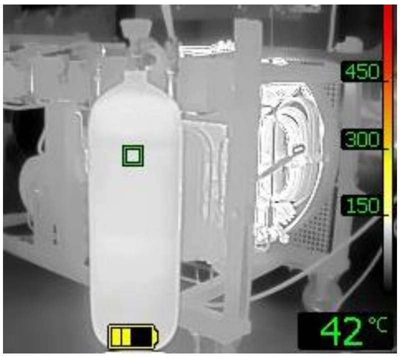

Figure 5. Temperature intensity in the upper half of the bottle, comp. bottle

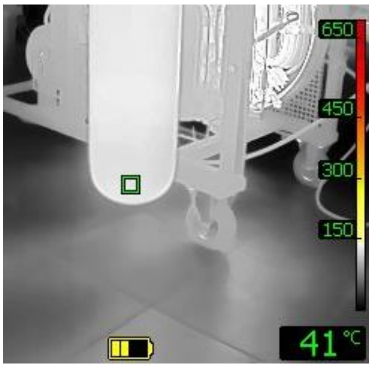

Figure 6. Temperature intensity at the bottom of the bottle, comp. bottle

There is no significant difference in the temperature of the temperature of the fillers from the steel or composite material at standard charge. These temperatures can not manifest significant temperature stresses in the walls of the bottle [3].

2.2. Filling the bottle from the medical air accumulator

Fast-loading the bottle of insulation devices is done from the battery (air bank). Banks can be stable and mobile. The bottling time at the nominal pressure (30 MPa) is up to one minute, according to the recommendations of the manufacturers of storage reservoirs for compressed air. This time can be regulated by the position of the flow valve, Figure 7. The capacity of the bank of air depends on the number and volume of individual bottles and the pressure of the air bank, Figure 8. [2].

Figure 7. Rapid charge control panel from the air bank

Figure 8. Bank of the air

The charging time may be shorter, as far as technical options are concerned (from 10 seconds to 60 seconds). However, there is a real danger of an accidental situation due to a dynamic (shock) change in the voltage state in the bottle material, where the value of the intensity of the voltage is far greater

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than the loading of the bottle with a slower increase in the pressure in the bottle. For this reason, research requires access to the identification of the intensity of the stress states in order to determine the parameters of the minimum time for fast bottling of the bottle with medical air that guarantees safety. The capacity of the air bank depends on the number and volume of individual bottles, and the pressure of the air bank. The dependence of the increase in pressure in fast charging in the function of time should be monitored with digital measuring equipment, as the bottling time of the bottle is quite short and there is a rapid increase in pressure. This rapid increase can cause an accident if the bottle is damaged during use, and the damaged has not been identified in time.

In addition, the air banks must be in conjunction with the compressor during their use, and the reason is that every bottle inflates the pressure in the air bank and the user bottle can not be filled to a nominal pressure of 30 MPa, Table 3.

Table 3. Drop of pressure and amount of air in the function of time-bank of air

Volume of the air bank l	Air pressure in the air bank (MPa)	Quantity of air m^3	Quantity of air l
150	30	4.5	45000
150	28.6	42.9	42900
150	27.2	4.08	40800
150	25.8	3.87	38700
150	24.4	3.66	36600
150	23	3.45	34500
150	21.6	3.24	32400
150	20.2	3.03	30300

The values in Table 3 are theoretical and, in real terms, a reduction of up to 10% can be counted as a result of losses resulting from manipulation during fast bottling. For this reason, it is necessary for the compressor to complement the air bank during interventions in order to be able to quickly flush the bottle at a nominal pressure.

3. Conclusion

When charging fast, it is necessary to take care of the correctness of the bottle, ie, that it was not damaged during interventions for the safety of its filling. In the event that the bottle is damaged, there may be severe consequences for the user. Fast charging should be done in one minute. Reduction of charging time leads to a reduction in safety. However, quick charging reduces the time up to 10 times in comparison to the classic bottling of the bottle. The disadvantage of the air bank is that it must be in conjunction with the compressor, if it is not continuously replenished, then it is impossible to fill more bottles at the nominal pressure as can be seen from the experimental testing of the pressure drop in the air bank in the case of quick bottling of several bottles.

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