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Investigations of the two-stage dust separator with a modernized axial cyclone

SUMMARY

Requirements for the contemporary ship dust separators and results of the investigations of three sucessively improved versions of axial cyclones used as the first stage of the dust separator with the sackcloth bag filter as the second stage are presented in the paper.

Dedusting effectiveness and working noisiness of the cyclone dust separators as well as hydraulic gradients and effectiveness of the two-stage dust separator were investigated.

INTRODUCTION

The dust released during reloading of the bulk cargoes penetrates into the most distant internal compartments of the ship. It concerns service compartments, living accomodations and power plant space. In the power plant space where the crew members are present the generating sets operate and absorbe the dusty air from the ship's environment.

Distribution of the dust concentration (s) varies in dependence on the wind direction and velocity as well as the distance from reloading place (l) as shown in Fig.1.

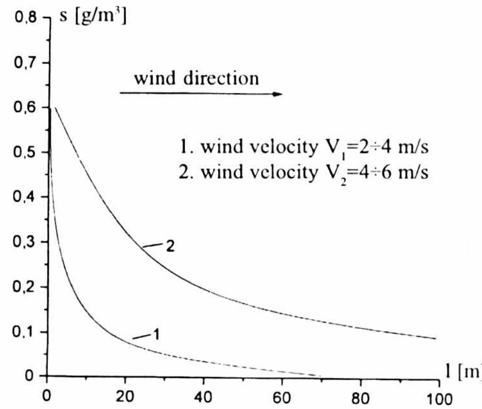

Fig.1. Variation of the dust concentration in air during reloading operations of the apatite in the port of Szczecin [4]

The conclusion of [1] is that the dust containing the particles of the diameter less than 5μm is the most harmful to the living organisms. The dust particles of 1÷5 μm diameter easily penetrate the alveolar sacs but it is hard to remove them. The particles lingering in the lungs have iritating effects and moreover they can stimulate inflammatory states. The organic dust is very dangerous to the human body, in particular that of grain, plant and animal fibres as well as fish flour, as they can be contaminated by moulds and pathogenic bacteria.

The dust particles of 5÷20 μm diameter cause very detrimental effects on ship machinery and equipment since their size is of the same order as the lubricating oil film thickness and therfore they penetrate along with the oil flow into the most distant regions of cooperating elements and cause premature wear of them [2, 3]. The durability drop of elements of the ship machinery and equipment clearly depends on the kind of dust material. The hard dust (e.g. of silicon dioxide) which does not undergo size reduction is especially damaging as it causes strong abrasive effects on all movable elements. The dedusting devices installed in the air intakes provide protection against harmful effects of the dust on human body and ship machinery.

DUST SEPARATORS FOR SHIPS, SHORTCOMINGS AND ADVANTAGES

The ship's dust separators, as service experience demonstrates, are expected to fulfil several conditions the most important of which are the following [5] :

- ability of operation in any climatic conditions
- small gabarites and limited weight
- resistance against corrosive action of the environment
- low hydraulic drag
- high efficiency
- easiness of maintenance

It is very difficult to satisfy all the conditions due to high cost of their realization. Therefore a limited cost should be considered as an important factor in selecting the separators. The air is absorbed through the intakes directly from the atmosphere surrounding the ship. The intakes are fitted with shutters and grids to stop water and large-size dust particles. Usually, dust-stopping dry filters of the pressed fibre mat are installed which is inconvenient because they become clogged after a short time of operation in spite of having the dust shaking-off devices and in consequence it makes the resistance of air flow grow fast.

The wet filters, another type of the dust separators, are so designed that the dusty air flows into a chamber with the internal nozzles which generate water curtain causing the dust particles become moistened. Mass of the particles grows and they fall onto the filter chamber bottom. Rest of the dust particles find their way to the filtering plate which is rinsed off to make its operation time longer without increasing the resistance to air flow. A scheme of the wet deduster is shown in Fig.2 [6].

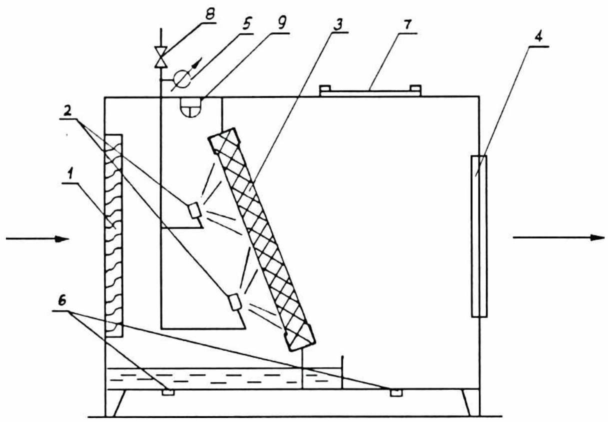

Fig.2. Scheme of the LVB water-rinsed-off air filter produced by Svenska Flaktfabriken
1- inlet grate, 2- water nozzles, 3- filtering plates, 4- air inlet with dedropping device, 5- water manometer, 6- water drainage, 7- inspection opening, 8- water control valve, 9- lighting

A shortcoming of the wet filters is that their dedusting effectiveness exceeds 90% only at the dust particles greater than 15 μm, i.e. of the size of the water spray particles. Their effectiveness drops below 50% at the dust particles less than 5 μm in size. A high water consumption of about 0.1 dcm^3 per $1m^3$ of air is an additional drawback which leads to more intensive slime formation.

Recently the two-stage dedusters whose first stage consists of axial cyclones and the second the sackcloth bag filters, are the object of the research aimed at developing the dust separators for marine applications.

RESEARCH ON OPERATION EFFECTIVENESS OF AXIAL CYCLONES

An axial cyclone used as the deduster was manufactured and tested in three versions. Each of them comprised one common element consisted of the worm with paddles of increasing slope angle and the swirl chamber containing the worm. The dusty air flow running onto the paddles is exposed to increasing centrifugal forces which put the dust particles to the accelerated motion towards the outer layer of flow. Uniform ducting of the air flow was obtained after adding the internal core with several swirl paddles symmetrically fitted on it. Version I and II differ from each other with the part which takes the dusted air off. An elongated separation chamber was used in the axial cyclone of version III, which made providing it with an auxiliary outlet stub pipe possible. The cyclone operates in accordance with the principles similar to those of the tangent cyclone. Effectiveness of the so designed cyclone deduster increased considerably.

Design schemes of the above described versions of the cyclone are shown in Fig.3, 4 and 5. Results of the dedusting effectiveness tests of the devices are presented in Tab.1.

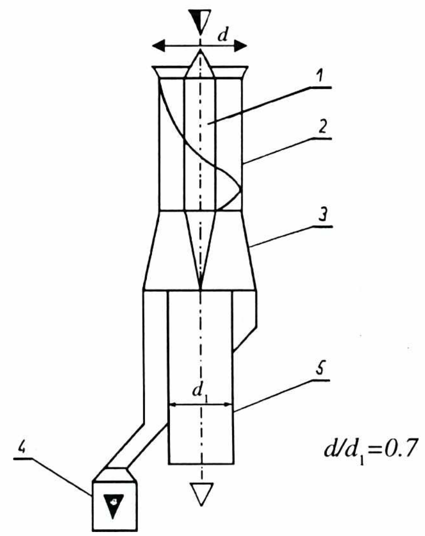

Fig.3. Scheme of the straight cyclone dust separator of version I
1- variable pitch paddle worm with internal core, 2- swirl chamber, 3- separation chamber, 4- dust container, 5 - outlet stub pipe

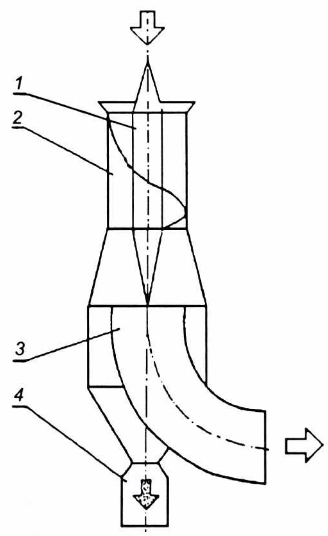

Fig.4. Scheme of the cyclone dust separator of version II
1- worm, 2- swirl chamber, 3- outlet stub pipe, 4- dust container

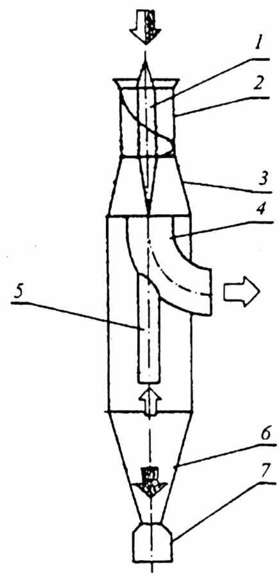

Fig.5. Scheme of the cyclone dust separator of version III
1- worm, 2- swirl chamber, 3- upper separation chamber, 4- outlet stub pipe, 5- auxiliary outlet stub pipe, 6- lower separation chamber, 7- dust container

Tab.1. Results of the dedusting effectiveness tests of the axial dust separators

Dust material	Dust density [kg/m³]	Total dedusting effectiveness [%]		
		version I	version II	version III
Coal	1310	78,4	88,2	93,5
Apatite	2330-2630	81,8	83,2	91-92
Phosphate	2787	81,2	81,1	88,3
Sulphur	2070	82,0	86,0	86,0
Iron ore	3950	83,3	89,0	95,2
Grain	247	78,2	87,6	96,5

Satisfactory values of the total dedusting effectiveness were obtained for the version III cyclone deduster only. The cyclone was subject to the dedusting effectiveness tests with taking into account the fraction ranges and dusty air velocity within the inlet choke. Results of the tests are contained in Tab.2.

Tab.2. Results of the dedusting effectiveness tests of the version III axial cyclone with respect to the fraction ranges and velocity of the apatite-dust air

Fraction range [μm]	Dedusting effectiveness [%] at the inlet velocity [m/s]							
	4,8	6,8	7,3	10,5	11,8	12,7	14,0	14,6
> 20	93,2	94,8	96,1	97,0	97,6	97,9	98,4	99,1
15-20	91,0	94,6	96,0	97,0	97,4	97,2	98,3	98,4
10-15	90,0	90,4	91,2	93,0	93,2	93,6	94,4	94,4
5-10	80,0	82,0	86,0	89,0	90,0	91,0	91,3	91,5
< 5	76,0	80,0	81,0	83,0	84,0	84,5	86,0	86,4
Average	86,0	88,0	90,0	91,8	92,4	92,8	93,7	93,9

It can be stated on the basis of the results given in Tab.2 that increasing the flow velocity over 12 m/s very slightly improves the cyclone operation effectiveness, moreover at those velocities a considerable increase of the deduster operation noisiness is observed. The measurements of the deduster operation noisiness were carried out with the use of Bruel&Kjaer noise meter of 2204-type, octave filter of 1613-type and microphone of 4145- type. Results of the noisiness measurements at the air flow velocities still ensuring the good dedusting effectiveness are presented in Tab.3.

Tab.3. Measurement results of the cyclone deduster noisiness at the air flow velocities still ensuring the good dedusting effectiveness

Flow velocity [m/s]	Acoustic pressure levels [dB] at the octave bands of the frequencies [Hz]									Noise level value
	31,5	63	125	250	500	1k	2k	4k	8k	AdB
11,8	73	65	60	53	42	34	30	20	19	47
14,6	80	78	81	83	80	75	66	56	47	80

It can be observed, when comparing the axial cyclone operation results presented in Tab.2 and 3, that the flow velocity of about 12 m/s is the most favourable as then both good dedusting effectiveness and low noise level is achieved.

INVESTIGATIONS OF THE TWO-STAGE DUST SEPARATOR OF THE AXIAL CYCLONE - SACKCLOTH FILTER ARRANGEMENT

The next investigation stage was realized with application of the test stand schematically presented in Fig.6.

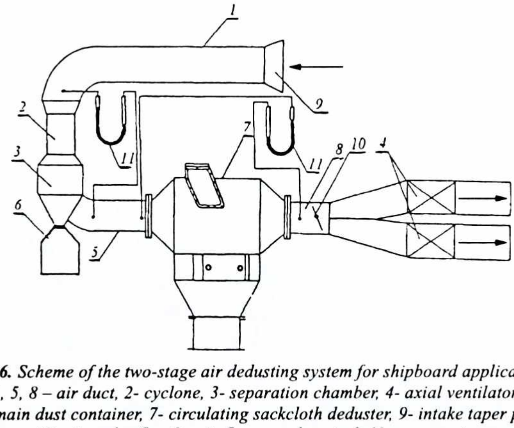

Fig.6. Scheme of the two-stage air dedusting system for shipboard applications 1, 5, 8 – air duct, 2- cyclone, 3- separation chamber, 4- axial ventilators, 6- main dust container, 7- circulating sackcloth deduster, 9- intake taper pipe, 10- strangler flap for air flow speed control, 11- manometers

The maximum dusty air flow rate available at the stand was 1300 m³/h. The cylindrical sackcloth filters applied to the dust separator in question had the flow rate up to the standards, i.e. its total area was more than 5 m². The polypropylene fabric was used due to its high mechanical strength, low hygroscopicity and lack of expanding, which guaranteed constant size of the filtering gaps [6]. Filters made of the fabric stop the fine grained dust very effectively. Each of the sackcloth filters was shaked off by means of a cam device to prevent dust accumulation on their surfaces. Pressure dropping within the cyclone section and separately within the sackcloth filter section was measured apart from the total dedusting effectiveness. Results of the measurements are collected in Tab.4.

Tab.4. Test results of the two-stage dust separator

Type of dust	Pressure gradient within cyclone [mm Hg]	Pressure gradient within fabric filters [mm Hg]	Total dedusting effectiveness [%]
Coal	230	260	99,4
Apatite	230	270	98-99,1
Phosphate	230	285	98,8
Sulphur	225	330	88,0
Iron ore	230	260	99,0
Grain	225	290	99,9

It can be seen from the analysis of the results given in Tab.4 that higher values of the resistance of air flow through the sackcloth filters are observed for some kinds of the dust. Therefore the conclusion on delivering the air into the entire machinery space, which is filtered out by the cyclone dedusters capable of separating 97% of the particles greater than 10 μm, seems to be justified. The sackcloth filters should be applied to the ventilation ducts delivering the air to the compartments in which people are present either during working hours (e.g. machinery control room, workshops, navigation bridge) or in rest time (living, social and recreation accommodations).

CONCLUSIONS

The tested two-stage dust separator of the axial cyclone-sackcloth filter arrangement can be characterized as follows :

- the first stage separates the coarse-grain particles from the air and therefore protects the sackcloth filter against fast clogging
- the sackcloth filter of the deduster second stage improves the total dedusting effectiveness up to 98% for most kinds of dust inclusive of that containing the particles of less than 5 μm.
- the proposed dust separating system enables to prepare the air free of the dust fractions harmful to living organisms, (1 to 5 μm) and machinery, (5 to 20 μm)
- lack of the movable parts makes operation of the dedusting system reliable.

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