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Explosion protection concept for liquid pumps of ATEX category 1

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Abstract

To increase the efficiency factor and safety of category 1 liquid pumps, the ignition hazard analysis and the requirements of monitoring devices have to be taken into account. The established certificates for category 1 liquid pumps require a minimum amount of liquid inside of the tank as a heat capacity and a minimum circulation volume of liquid through the bypass pipe to ensure the temperature class of the pump. In addition, the tank needs to be protected against ignition sources with a flame arrestor in the bypass pipe and with a foot valve inside of the pump. These autonomous protective systems require frequent maintenance to function reliably. This article provides guidance for the requirements of non-electrical explosion-protected equipment under application of monitoring devices, e.g. for flow and the liquid level inside of the tank, to avoid an ignition source in the interior of the pump. To complete the category 1 requirements for the outside surface the temperature of the pump body is limited. The requirements for the control of ignition sources for non-electrical equipment will be explained. All in all, an overview for submersible pumps in hazardous areas will be given.

Keywords

Explosion protection, ignition source, ignition hazard analysis, protection concept category 1, monitoring devices, control of ignition sources, ATEX

1 Introduction

Submersible pumps can become an ignition source in potentially explosive atmospheres. To avoid having an ignition source, measures must be taken which do not lead to ignition, even if all other conditions of ignition exist, thus under the most unfavourable safety-technical conditions (worst case). These measures consist of constructive aspects, monitoring devices for external parts of the pump and in part, of the displacement of the potentially explosive atmosphere in the interior of the pump in the majority of operating conditions.

Explosion-hazardous areas are the working environment of people; the legal regulations of industrial safety are effective here. The Explosion Protection Directive 94/9/EC (ATEX) requires the avoidance of potential ignition sources in explosion-hazardous areas and points at, among other things, mechanical sparks and hot surfaces as an ignition hazard [1]. In this Directive, however, no measures are specified. The measures to be considered are generally described in harmonised European standards. For submersible pumps, some serious changes compared to e.g. the previous national (German) rules of the VbF have become effective due to this standards situation [2]. For submersible pumps of category 1 (ATEX), a general safety concept is to be described in the following:

The safety concept is based on a combination of preventive and protective measures which on the one hand diminish the probability of an ignition source becoming effective and on the other hand avoid the explosive atmosphere coming into contact with potential ignition sources.

2 Designs

For submersible pumps, distinction is made between two possible designs: submersible pumps with integrated, submersed motor (Figure 1). Here, the motor is located in the tank (defined as Zone 0) and is exposed to liquid or covered under liquid as an internal part of the pump. The liquid cover is adequate monitored. The second design, having its drive above (Figure 2), uses an external motor outside of the tank. In the case of the pump having its drive above, explosion-protected standard motors can be used. The separation between the tank or pump pipe and motor must exclude a shifting of zones here. The submersible pumps with external drive are to be discussed further here.

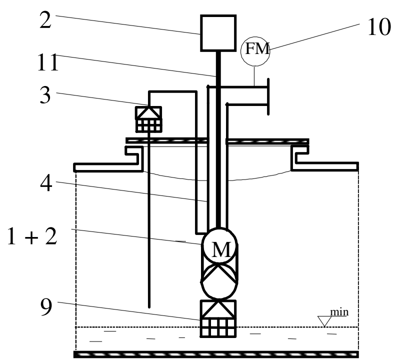

Figure 1: Submersible pump with submersible motor

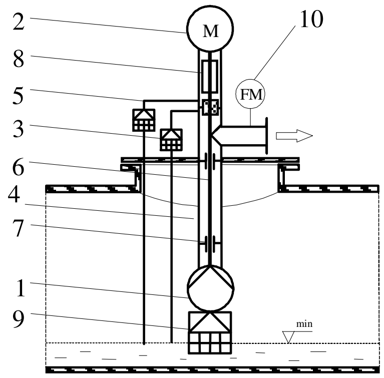

Figure 2: Submersible pump with external motor

1 Submersible pump; 2 Motor; 3 Bypass pipe; 4 Standpipe; 5 Leakage pipe; 6 Pump shaft; 7 Shaft bearing; 8 Natural ventilation; 9 Foot valve; 10 Flow monitoring device; 11 Cable conduit

3 Requirements

In the case of pumps according to the concept of the German VbF (see Figure 3), there was no formal ignition-hazard assessment. The pumps have a return pipe for the collection and return of quantities leaked from the slide ring seal. Another pipe is - as temperature balance - returned as bypass pipe into the tank. In the bypass pipe, the bypass quantity is adjusted by means of the apertures. A minimum amount of liquid is required for collecting the heat. The ignition hazard due to hot surfaces is to be reduced herewith. The bypass and leakage pipes are safeguarded by protective systems against the penetration of flames from the pump into the tank. The main pipe of the pump is - with a foot valve as autonomous protective system - also safeguarded against the penetration of flames into the tank. As additional protective measures, a flow controller and a redundant tank-fill-level monitoring device have been provided. The filling of the pump with liquid is to be achieved herewith. A dry-run condition of the pump which would create potential ignition hazards will be reduced to a minimum thereby.

The problems arising from the new legal foundations (ATEX) essentially result from the modified standards requirements of the EN 13463-1:2001 for non-electrical equipment [3]. With the method of diverting the heat in the tank via the bypass pipe and to use the minimum residue volume as heat capacity, no temperature limit is reached. Surfaces hot enough to be ignition sources appear only delayed. However, a steady-state temperature is not reached. This would be necessary, however, to limit the surface temperature and to determine a temperature class. The bypass quantity produces, due to the required reverse flow, a reduced degree of efficiency for the pump. The flame arrestor produces a flow resistance in the bypass pipe and is, due to its design, sensitive to contamination. Frequent cleaning at regular intervals is thus necessary to maintain the bypass quantity. The foot valves utilised as flame arrestor according to EN 12874 are, due to the expected malfunction of being contaminated, in an unusual manner not closed. Contrary to former testing practice, the valves are open with the contaminations of at least 3.5 mm, predetermined by the intake screens [4]. An effective function as flame arrestor is thus doubtful.

To evaluate the non-electrical portions of the pumps in accordance with the newest concept of the ATEX and following the standards series EN 13463-1 (see Figure 4), the ignition hazards of individual components will be examined in detail. For this examination, the respective requirements are linked to the design of the devices. There are initially no restrictive requirements, but rather the assessment of the potential ignition hazards is carried out exclusively according to the frequency of the occurrence and the ignition capability of the ignition source. It must be decided whether safe operation of the device is possible without the use of protective systems. In this connection, there is the possibility of fulfilling the requirements of the device even without protective systems, by the assured avoidance of ignition sources inside of the pumps. One must consider hereby whether the utilisation of protective systems in addition to the pump as device, e.g. according to TRbF, is obligatory [5]. The necessary measures are derived from the following ignition hazard assessment:

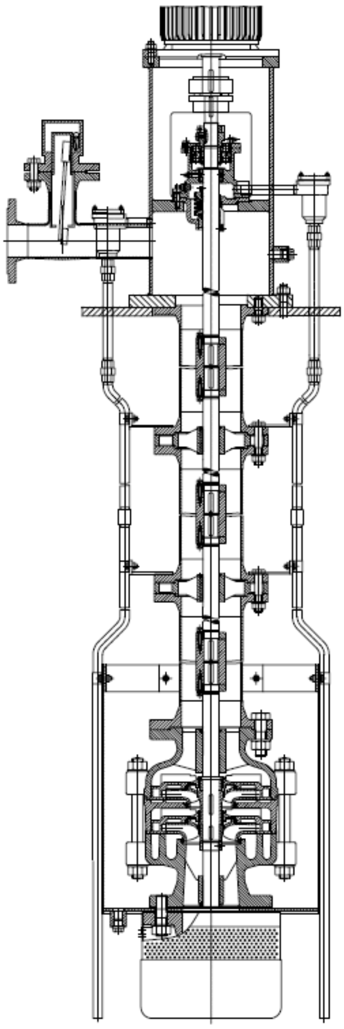

Figure 3: Pump VbF (Germany)

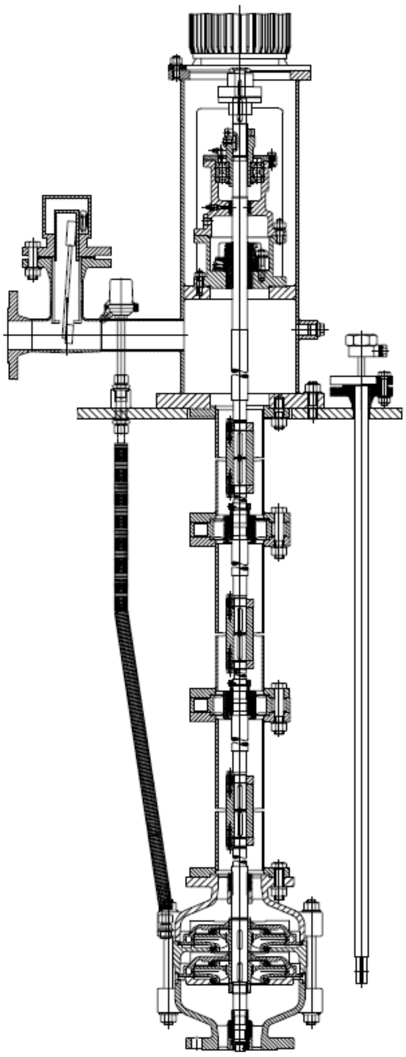

Figure 4: Pump ATEX

4 Ignition hazard assessment

Table 1; part 1: Ignition hazard assessment according to prEN 13463-1:2007-03 for a submersible pumping unit [6], [7].

Ignition Hazard Assessment Report: Submersible pumping unit (incomplete)																
	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional protective measure					Measures applied to prevent the ignition source becoming effective			Frequency of occurrence incl. all protective measures					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
No.	potential ignition source	basic cause / description (Which conditions originate the ignition hazard ?)	during normal operation	during foreseeable malfunction	during rare malfunction	not to be considered	reasons for assessment	description of the protective measure	basis (standards, technical rules, experimental results)	evidence (including relevant features listed in column 1)	during normal operation	during foreseeable malfunction	during rare malfunction	not to be considered	resulting equipment category in respect of this ignition hazard	necessary restrictions
1	electrostatic discharge	isolated conductors	x				isolated conductors create a capacitor which may be hazardous charged	equipotential bonding between the parts; installation instructions in user´s manual	EN 13463-1:2000, no. 11	user´s manual; chapter XY				x	1	-
2	electrical spark	shifting of the zone; explosive atmosphere out of the inner pump housing is inserted into the electrical motor			x		may occur if the slide ring seal is leaky	all parts of the sealing system are designed for the operating pressure; an adequate natural ventilation is foreseen at the slide ring seal		design; routine test				x	1	-
3	hot surface	friction in the slide bearings inside of the pump´s standpipe			x		dry run of the inner parts of the pump	the intended use requires a permanent filling with liquid inside of the pump´s standpipe; exclusion of the dry run by two independent means of control of ignition sources, flow monitoring (IPL 1) and liquid level monitoring (IPL 1)	EN 13463-6:2005	user´s manual, chapter XY; EC-type examination certificate for the use in explosive atmospheres and the use as a monitoring device for control of ignition sources "b", marked b1 according to ignition prevention level 1 (IPL 1)				x	1	-
4	hot surface	friction in the slide bearings inside of the pump´s standpipe	x				dry run of the inner parts of the pump at the start of operation; unavoidable time to switch the flow monitoring device	non-sparking material with failsafe running functions; temperature is determined under the most adverse conditions, dryrun test	EN 13463-1:2001, EN 13463-5:2003 annex B	temperature type test report; limitation of the dryrun conditions up to a maximum X of minutes (reaction time of the monitoring device)				x	1	T3
5	hot surface	heating of the pump during the operation against a closed gate valve			x		ignition source due to heated up parts of the pump´s housing; malfunction of the flow monitoring device	temperature is determined under most adverse conditions, a temperature limiter (IPL 1) is mounted at the pump´s housing	EN 13463-1:2001, EN 13463-6:2005	EC-type examination certificate for the use in explosive atmospheres and the use as a temperature monitoring device for control of ignition sources "b", marked b1 according to ignition prevention level 1 (IPL 1)				x	1	T4
6	hot surface	falling liquid level inside the tank down to the intake of the pump			x		ignition source due to heated up parts inside of the hydraulic of the pump	liquid level monitoring (IPL 1) inside of the tank, to avoid an explosive atmosphere inside of the pump; a failure of the level monitoring system will be detected, flow < than minium flow rate	EN 13463-6:2005	EC-type examination certificate for the use in explosive atmospheres and the use as a monitoring device for control of ignition sources "b", marked b1 according to ignition prevention level 1 (IPL 1)				x	1	-
7	hot surface	unexpected friction of the shaft and housing parts			x		friction due to vibrations	calculated stability of the parts, maximum shaft length is defined, limit value for vibration is determined, critical revolution is avoided		design; user´s manual; routine test				x	1	-
8	mechanical spark	a grinding rotor at dry run conditions			x		mechanical grinding of the rotor because of corrosion, reduction of the gap will be considered; aluminium and rusty steel may generate termite sparks	stator material shall not contain rusty steel or friction sparks are excluded by means of control of ignition sources (liquid exposure).	EN 13463-1:2001, clause 8.2 EN 13463-6:2005, 8	- specifications of the material (clause 8.2); - parts list, pos. X (or drawing No. Y) - specifications of the control of ignition sources (IPL 1);				x	1	-
9	mechanical spark	breakdown of the ball bearing of the shaft guiding		x			the external bearing is close to the pump housing	the lifetime of the bearing is calculated; the maintenance and the lubricant is defined, the inner volume of the pump is filled with liquid	EN 13463-1:2001 ISO 281	design; user´s manual; routine test			x		2	-
Resulting equipment category including all existing ignition hazards:															1/2	T3

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Table 1 shows an example of an ignition hazard assessment for a submersible liquid pump of category 1. It gives an (incomplete) example of how to record the ignition hazard assessment for a submersible pump of category 1 inside of a tank and for category 2, outside of the tank. It is not definitive and alternative measures could be applied.

In general, potential ignition hazards due to hot surfaces, mechanical sparks and electrostatic charging, e.g. will be considered. Mechanical sparks can be generated by the grinding of rotating parts and the housing, or contacts with contaminants of the liquid. Other possibilities for grinding contact are vibrations of the shaft due to critical revolution speed or as a result of a bearing failure. The pump will be planned and manufactured so that it fulfils its safe function within the limits of the operating conditions.

For category 1 equipment, rare malfunctions as well as ignition hazards, as a result of two expected malfunctions, will be considered. As example, the failure of a slide bearing of the shaft guiding is mentioned. The bearings are used inside of the pump and can be assessed with category 1 requirements. Because of this, an appropriate action is indispensable. Other examples are insufficient stability, loss of parts, failures of safety devices or the intrusion of explosive mixtures into inadequately protected parts of the equipment due to defective separation elements, e.g. gaskets or rotating mechanical seals. For category 1, combinations of two rare malfunctions, or a rare malfunction in combination with an expected malfunction, can be disregarded. In these cases, an ignition hazard is regarded as sufficiently improbable.

The examples given in Table 1 do not generally require a special explanation. For individual items, however, a more elaborate explanation would be helpful. Under certain conditions it may be difficult to recognise ignition hazards, as they only occur during error conditions. An explosion-protected motor can become an ignition source when unintentionally, the potentially explosive atmosphere is continually present. This can happen when the ventilation of the zone separation element between Zone 0 and Zone 1 has not been incorporated in the design of the pump components. Depending on the type of the protective measures, also combinations of the construction design and the monitoring devices may be necessary.

In line 4, a surface becoming effectively hot is excluded due to the slide bearings of the shaft duct, through the combination of the utilisation of bearings with dry-run characteristics and covering with liquid. Depending on the design, it may be technically necessary to dry-start the pump for the initial operation to build up the liquid flow. The flow controller recognises the liquid cover achieved by flowing liquid, only with a delay.

In other cases, one may and must assume that monitoring devices seldom fail during operating malfunctions. The pump assembly requires a temperature limit to guard against a defective flow controller. A fill-level monitoring device in the tank ensures that in the operation of the pump there is a liquid column present inside the pump. Falling below the minimum flow rate remains unknown, however. An accumulation of mechanical losses may occur which will cause a rise in temperature. For this reason, the pump housing is protected against inadmissible heating with a temperature limiter. A defective temperature limiter does not automatically lead to inadmissible heating, because in normal operation the pump does not have inadmissible heating above the minimum volume flow. In case of a defective fill-level monitoring device, no-load operation can be excluded because the flow controller would prevent dry running. If the availability of the monitoring devices is ensured by periodic checking within the scope of maintenance and by the use of operationally proven components, then a failure of the monitoring devices can be accepted as a rare malfunction. A simultaneous failure of several monitoring devices is then sufficiently improbable.

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If various models of pumps are used, then the ignition hazards will change as well as the necessary measures. By shifting the pressure pipe to the exterior, the necessary lubrication of the slide bearings is ensured (regarded as a measure). This measure can be realised by a pressure-powered return-flow pipe. By filling the pump's (interior) space with liquid and a fill-level monitoring device, the goal, equivalent in a safety-technical sense, can be attained. This modification can be documented as follows:

Table 2: Variation of an ignition hazard assessment according to Table 1 for a submersible pumping unit

Ignition Hazard Assessment Report: Submersible pumping unit (incomplete)																
	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional protective measure					Measures applied to prevent the ignition source becoming effective			Frequency of occurrence incl. all protective measures					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
No.	potential ignition source	basic cause / description (Which conditions originate the ignition hazard ?)	during normal operation	during foreseeable malfunction	during rare malfunction	not to be considered	reasons for assessment	description of the protective measure	basis (standards, technical rules, experimental results)	evidence (including relevant features listed in column 1)	during normal operation	during foreseeable malfunction	during rare malfunction	not to be considered	resulting equipment category in respect of this ignition hazard	necessary restrictions
1	hot surface	friction in the slide bearings inside of the pumps standpipe			x		dry run of the inner parts of the pump	the intended use requires a permanent filling with liquid inside of the pumps standpipe, exclusion of the dry run by priming the pump before start of operation and means of control of ignition sources, inner liquid level monitoring (IPL 1)	EN 13463-6:2005	user´s manual, chapter XY; EC-type examination certificate for the use in explosive atmospheres and the use as a monitoring device for control of ignition sources "b", marked b1 according to ignition prevention level 1 (IPL 1)				x	1	-

The design attains a protection goal equivalent in a safety-technical sense in various ways. The liquid cover is no longer achieved directly through the flowing medium, but rather indirectly by filling with a protective liquid. This liquid level can be ensured with a monitoring device. A further variation of filling the standpipe could be achieved by means of external, pressure-powered flow pipes (see Figure 5). The design of the pumps differs distinctly from one another, however, as can be seen in Figures 5 and 6.

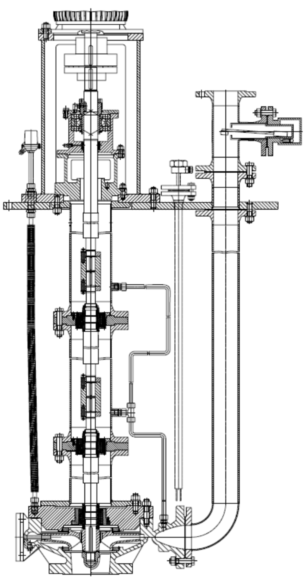

Figure 5: Pump with external pressure pipe

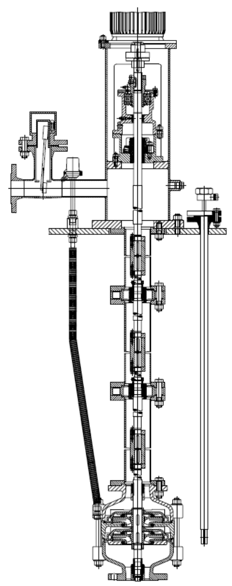

Figure 6: Pump with internal pressure pipe

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In this connection, it is easily discernible how the consideration of the individual ignition hazards is transferable to diverse structural shapes.

5 Safety devices in the type of protection “b”

The monitoring devices according to EN 13463-6; Protection by control of ignition source “b” attract attention, due to the fact that they are protective measures necessary for safe operation [8]. New here is the requirement of an ignition prevention level (IPL). Before a decision is made to protect equipment, a determination of suitability of parameters for the control of ignition source has to be carried out. Parameters for ignition source prevention are in the example of the above-mentioned pump components: flow rate, temperature and fill level. Such monitoring devices can generally be obtained also with a declaration of conformity according to Directive 94/9/EC (ATEX) for use in explosion-hazardous areas. Often, however, no statement is made about its suitability as safety device with proven operational safety according to EN 13463-6.

The suitability of the ignition protection system must, however, be evaluated thoroughly. Hereby, the sensors, evaluation units and actuators, as well as the switching into a safe condition are to be taken into account. The components cannot be evaluated separately from one another. It is necessary to take into account the speed at which a potential ignition source can become an effective ignition source. The ignition prevention system must have a sufficient response factor. In addition, safety factors must be provided. Besides further requirements which are stated in EN 13463-6, attention must particularly be paid to the availability of the ignition prevention system. The ignition prevention system may not fail, unrecognised, over longer periods of time. The availability of the protective function must be ensured by sufficiently low error probabilities and by a suitable, periodic checking within the scope of the maintenance.

Another item is added due to the conformity assessment procedures specified by Directive 94/9/EC. The conformity assessment procedure for the monitoring devices, particularly the monitoring function, depends on the category of the non-electric device to be protected. For non-electric category 1 devices that means, in addition to a measure for the quality assurance, an EC-type-examination test for the monitoring device. This test can be integrated into the test of the pump device. It is also possible to use a monitoring device for non-electric category 1 devices with a separate EC-type-examination test and declaration of conformity. Such monitoring devices must then be marked, e.g. for ignition prevention level 1, with "b1" as monitoring device according to EN 13463-6.

If submersible pumps with integrated motor, as e.g. pumps, are used in petrol filling stations, then the applicable standards change. The motor is exposed to liquid as an internal part of the pump. These submersible pumps are subject to prEN 15268:2007-08 [9]. Due to the integrated motor, the assembly is deemed to be an electrical device and this results in a difference in the handling of the monitoring devices. As the devices concerned hereby are electrical devices to be monitored, the requirements for the monitoring devices are regulated by prEN 50495:2006-08 [10]. These requirements are not to be dealt with further here, however.

6 Conclusion

For the practice of the non-electric devices, the following changes have resulted. The operating manual points to the periodic testing as well as the tests before the initial placing into operation. Before being placed into operation, the monitoring devices (fill-level monitor, temperature limiter and flow controller) are to be adjusted to the required switching thresholds and to be checked for functional capability. Operation in a potentially explosive atmosphere may not be carried out until testing has been successfully completed. Operation without the stipulated monitoring devices is to be excluded by the operating company.

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For alternative monitoring devices desired by the operator, an ignition prevention level - depending on the requirement - of IPL 1 or IPL 2 according to DIN EN 13463-6 is necessary. Hereby, the measuring chain must be re-evaluated, if applicable, according to the requirements of Directive 94/9/EC, Annex II, paragraph 1.5 and EN 1127-1 [11], paragraph 6.7, as well as EN 13463-6. The maximum admissible ambient temperature, e.g. 60 °C, must be taken into account in the determination of the switching thresholds. Temperatures deviating from the normal ambient temperature must be known for the designing of the pumps as well as for the testing.

Submersible pump components, as non-electrical devices, are subject to new requirements of the standards series EN 13463ff. Compared with previous practice, a steady-state temperature is required. This temperature is regarded as reached when a temperature rise of less than 2 K/h is reached or a turn-off device turns off the pump. Monitoring devices must be assessed as ignition prevention system and show an ignition prevention level according to EN 13463-6. The integration of protection systems is not mandatory from the perspective of device testing.

6 Bibliographic details

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