

Active Gas Environment for Welding and Related Processes

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Abstract. The methods of activation of the gas environment, which is formed during the combustion of combustible gases in oxygen or formed in a plasma flow based on technical kerosene, are presented. The active gas component, which is boron trifluoride in the form of kerosene or boron trifluoride etherate, is added directly to the working environment. Activation of surfaces in contact with gas and plasma flows occurs due to the interaction of boron trifluoride with surface metal oxides, forming a fusible or gaseous slag that is easily removed from the surface. A simple work cycle, a minimum of standard equipment and preparatory operations, ensure effective, stable activation of the surfaces of heat-resistant alloys in the temperature range of 1000-1200°C. On the basis of studies of interaction processes, when surfacing the wear-resistant composition KBNHL-2 on the heat-resistant nickel alloy VZh-98 with a chromium content of up to 26% by weight, it is shown that the use of an activator significantly improves the adhesion activity of the surface. The wetting angles are within acceptable limits of 10-20° and can be easily adjustable due to visual temperature control. The proposed model of gas medium activation can be used for processing metals, their melting, soldering or heating in welding production and related processes. © 2026 Bull. Natl. Acad. Sci. Georg.

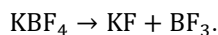
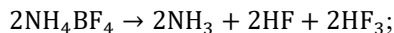
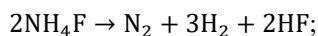
Keywords: gas environment, active gases, plasma, boron trifluoride, surface activation, surfacing

Introduction

The employment of active gaseous substances for the activation of surfaces prior to joining is well-established in soldering, welding, and associated fields. Fluxes – which can exist in solid, liquid, or gaseous – are employed to activate these gaseous media (Yermolaiev et al., 2015).

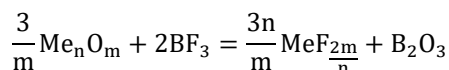
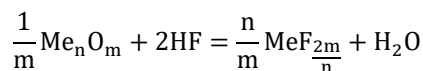
Gaseous fluxes serve both as standalone substances and as activating agents in conjunction with neutral or reducing media. Active gaseous fluxes are derived from the decomposition of metal fluorides and chlorides. The initial substances used to create these media are ammonium fluoride (NH₄F), ammonium fluoroborate (NH₄BF₄), potassium fluoroborate (KBF₄), among others. The decompo-

sition of these compounds occurs at elevated temperatures through reactions such as:



Ammonium fluoride undergoes complete decomposition within a temperature range of 600-800°C, while ammonium fluoroborate decomposes at temperatures ranging from 850 to 950°C, and potassium fluoroborate decomposes within a range of 800-900°C.

Surface activation results from the interaction between these decomposed products, namely hydrogen fluoride and boron trifluoride:



The optimum efficiency of these reactions is observed within the temperature range of 1000-1200°C, facilitating the activation of surfaces, particularly those composed of stainless steels and certain heat-resistant alloys.

The predominant method for surface activation in preparation for joining involves furnace heating of parts within an argon environment, which is activated by the decomposition products of the aforementioned substances (American Welding Society Committee on Brazing and Soldering, 2007). These substances are employed in both solid forms, such as powder, which generates an active gas component upon heating, and in gaseous states. Common practice involves introducing powdered forms of ammonium fluoride, ammonium fluoroborate, or potassium fluoroborate into the argon environment, where they decompose upon heating and flux the surfaces of stainless or heat-resistant alloys during joining. Enhanced outcomes are achieved by directly introducing activating substances, such as hydrogen fluoride or boron trifluoride, into the furnace atmosphere, thereby

stabilizing the activation process (Yermolaiev et al., 2015). Both approaches yield the requisite degree of surface activation, yet the utilization of boron trifluoride proves more effective. However, it should be noted that the furnace heating method typically exhibits lower productivity levels.

A known method of activating a gas medium is implemented in the KGF-3-71 gas-flux processing unit (Sokolov, 1988). This setup consists of a GS-3 welding torch, an FGF-3-71 flux feeder (which saturates the combustible gas with vapors of the liquid flux BM), and an OAF-3-71 dryer that dries and purifies the gas. Using this equipment, boron-menthol fluxes BM-1 and BM-2 are introduced in vapor form into the combustible gas, which burns in the torch and forms the active substance B_2O_3 , serving as a fluxing agent.

However, this method has several disadvantages. It involves a complex, multi-step process and operates within a narrow temperature range that is insufficient for effective activation of heat-resistant alloys at 1000-1200°C.

Considering the limitations of existing methods for activating the working environment in soldering, welding, and related technologies, this study aims to develop new approaches to gas flame and plasma activation. These approaches should feature a simplified operating cycle, minimal standard equipment and preparatory steps, and provide effective, stable activation within the 1000-1200°C range, while generating gaseous reaction products that are easily removed from the treated surface.

The proposed approach in the study involves integrating a heating source with an active gas medium, thereby significantly enhancing the productivity and quality of surface heating and activation processes for joining or treatment (Kostin & Martynenko, 2017; Kostin et al., 2018).

This task is addressed by utilizing a universal gas cutter of the P1 type (serial) as a burner for heating the activated surface. Various combustible gases such as acetylene, propane-butane, methane, and the methylacetylene-allene fraction, along with

an oxidizer like oxygen, can be employed for this purpose (Fig. 1). Acetylene is preferred due to its high calorific value and its ability to regulate the activity level of the gas environment through the presence of free carbon, particularly when combined with oxygen in specific ratios. The active gas component, such as boron trifluoride, is supplied to the heating zone via a separate channel directly from the storage cylinder.

This study proposes the integration of a heat source with an active gaseous medium, which enables a substantial improvement in the efficiency and quality of heating and surface activation processes of the materials being joined or treated (Kostin & Martynenko, 2017; Kostin et al., 2018).

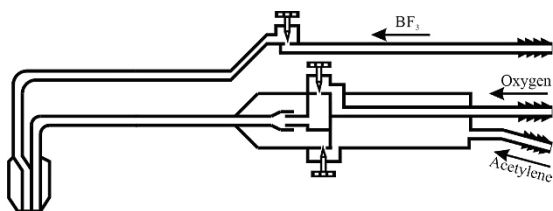
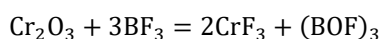


Fig. 1. Schematic diagram of a burner with an active gas medium.

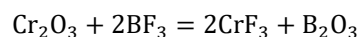
The concentration of the active gaseous substance in the heating zone is subject to considerable variation across a broad spectrum, contingent upon the type of activator and the metal undergoing activation. This concentration is directly regulated by the reducer. The primary criterion in this context is the condition of the activated surface and the existence of solid residues resulting from the interaction between the gaseous medium and the surface.

At operational temperatures, boron trifluoride engages in reactions with metal oxides, a process exemplified by its interaction with chromium oxide:



Under these circumstances, gaseous boron fluoride can be readily expelled.

However, if there is an inadequate quantity of boron trifluoride present in the interaction zone, the reaction proceeds as follows:



In such instances, the accumulation of solid B_2O_3 and CrF_3 residues intensifies, resulting in the formation of a relatively low-melting slag. This slag's quantity can be easily monitored visually, as it increases significantly.

In this scenario, there is a notable increase in the quantity of solid B_2O_3 and CrF_3 residues, forming a relatively low-melting slag, the amount of which can be easily visually monitored.

The proposed process scheme offers an effective method for activating an acetylene-oxygen flame by directly introducing boron trifluoride in gaseous form (Kostin & Martynenko, 2017).

Similarly, a plasma flow can be activated to enhance its reactivity, enabling efficient and stable surface activation of heat-resistant alloys within a temperature range of 1000–1200°C. This process results in the formation of gaseous reaction products that can be easily removed from the treated surface.

For instance, plasma generated from a water-alcohol mixture is commonly used. During the ionization of water, two volumes of hydrogen ions and one volume of oxygen ions are produced. These ions have a detrimental effect and do not ensure effective activation of treated surfaces, particularly those made of heat-resistant alloys in the range of 1000–1200°C.

The problem of plasma flow activation can be addressed by using a universal plasma torch – such as the one incorporated in the Multiplaza installation – as a heating source for the surface to be treated (Fig. 2). Technical-grade kerosene (TU38.201-58-8) serves as the base of the working solution, in which an active component, such as boron trifluoride, is dissolved in the form of boron trifluoride etherate (TU 6-09-804-77).

The volume fraction of the active substance may vary widely depending on the type of activator and the metal being treated. In this case, an important criterion is also the condition of the

treated surface and the presence (or absence) of solid residues resulting from the interaction between the plasma gas medium and the surface.

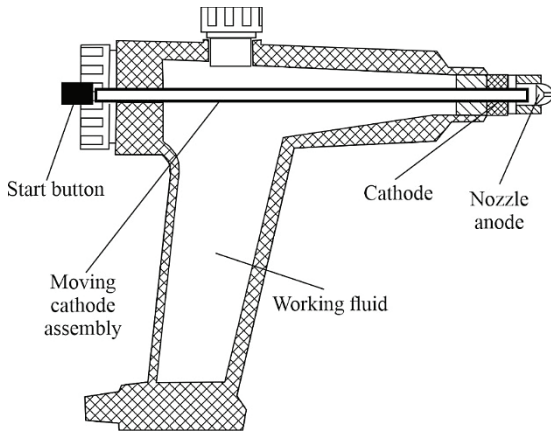


Fig. 2. Schematic diagram of a plasma burner with an active gas medium.

Thus, the method of plasma flow activation utilizing technical kerosene involves the direct addition of boron trifluoride in the form of boron trifluoride etherate to the working solution (Kostin et al., 2018).

It is crucial to emphasize the importance of strictly adhering to safety regulations when handling boron trifluoride (Regulation (EU) No. 1907/2006 of June 18, 2017). This regulation outlines specific safety protocols and guidelines that must be followed to ensure the safe handling and use of boron trifluoride in industrial applications.

The effectiveness of surface activation was evaluated through testing, wherein a wear-resistant composition KBNHL-2, characterized by a melting point of approximately 1070°C, was deposited onto a plate composed of the heat-resistant nickel alloy VZh-98, containing up to 26% chromium by mass. Additionally, for comparison purposes, surfacing using an acetylene-oxygen flame was conducted

without the inclusion of boron trifluoride. The chemical compositions of both the VZh-98 alloy and the wear-resistant composition KBNHL-2 are detailed in Table.

Analysis of the test results showed that the use of an acetylene flame alone yielded negative outcomes. The wetting angles between the VZh-98 alloy and the KBNHL-2 composition ranged from 45° to 60° (see Fig. 3a), and the surface exhibited a heavily oxidized appearance. This indicates poor adhesion and an unsatisfactory result.

However, when the KBNHL-2 alloy was applied to a VZh-98 alloy plate using an acetylene-oxygen flame activated by the addition of boron trifluoride gas, a positive outcome was achieved. The treated surface had a silvery appearance, indicating effective oxide removal (see Fig. 3b). The wetting angles between the VZh-98 alloy and the KBNHL-2 composition fell within the acceptable range of 10°-20° and could be easily controlled through visual temperature monitoring, confirming the effectiveness of this surface activation method.

A similarly positive result was observed when welding the KBNHL-2 alloy onto the VZh-98 alloy using a plasma flow based on technical-grade kerosene, activated by the addition of boron trifluoride etherate. The surface exposed to the active plasma medium also exhibited a silvery appearance, indicating successful oxide removal. The contact angles remained within the permissible range of 10-20 degrees and were likewise easily regulated through visual temperature control, thereby confirming the achievement of the desired technical outcome when activating the plasma flow with boron trifluoride etherate (Kostin et al., 2018).

Table. Chemical composition of VZh-98 and KBNHL-2 alloys

Alloy	Ni	C	Si	Ti	Cr	Fe	CrB ₂	Cr ₃ C ₂	Mn	W	Co	B
VZh-98	base	≤0.1	≤0.8	0.3-0.7	23.5-26.0	≤0.4	-	-	≤0.5	13.0-18.0	-	-
KBNHL-2	35.5-36.5	-	-	-	24.5-25.5	-	2.5-3.5	11.5-12.5	-	-	20.5-21.5	2.9-3.1

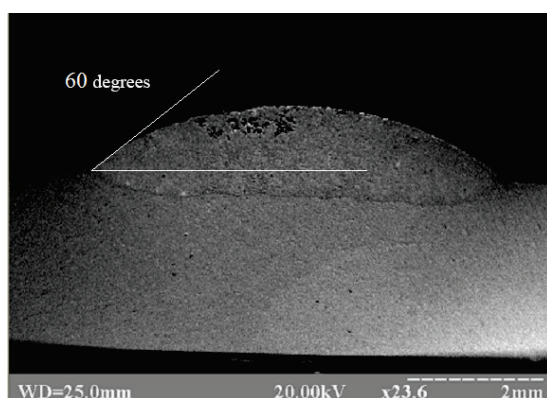
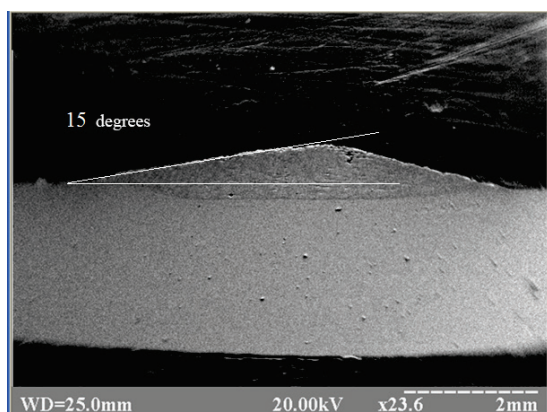


Fig. 3. Macrostructure of the interaction zone between the KBNHL-2 alloy and the VZh-98 alloy during welding with an acetylene-oxygen flame: (a) without the addition of boron trifluoride gas, and (b) with the addition of boron trifluoride gas.

Thus, in both cases, a positive result is achieved due to the activation of the heating sources – namely, the acetylene-oxygen flame and the plasma

based on a solution of technical-grade kerosene – by boron trifluoride gas or boron trifluoride etherate. This ensures effective and stable activation of the surfaces of heat-resistant alloys within the temperature range of 1000-1200°C, with the formation of gaseous reaction products that are easily removed. This outcome is considered both acceptable and sufficient.

The proposed methods for activating the gaseous environment can be applied to metal processing, including melting, soldering, or heating in welding and related manufacturing processes.

Conclusion

Activation of a gas flame based on combustible gases can be achieved through the direct addition of boron trifluoride gas, which significantly enhances the efficiency and quality of the heating and surface activation processes for joined or treated materials.

Activation of a plasma flow based on technical-grade kerosene is accomplished by directly adding boron trifluoride etherate to the working solution. This ensures effective and stable surface activation due to the formation of gaseous reaction products that are easily removed from the treated surface.

The proposed gas environment activation models provide effective and stable surface activation of heat-resistant and high-temperature alloys within the temperature range of 1000-1200°C.

მასალათმცოდნეობა

აქტიური გაზური გარემო შედუღებისა და მომიჯნავე პროცესებისთვის

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ნაშრომში წარმოდგენილია ჟანგბადში საწვავი გაზების წვისას ან ტექნიკური ნავთის ბაზაზე არსებულ პლაზმურ ნაკადში ფორმირებული აირადი გარემოს გააქტიურების მეთოდები. აქტიური გაზური კომპონენტი, რომელიც არის ბორის ტრიფტორიდი ნავთის ან ბორის ტრიფტორიდის ეთერატის სახით, უშუალოდ შეჰყავთ სამუშაო გარემოში. გაზურ და პლაზმურ ნაკადებთან კონტაქტში მყოფი ზედაპირების გააქტიურება მიმდინარეობს ბორის ტრიფტორიდისა და ლითონის ზედაპირული ოქსიდების ურთიერთქმედების შედეგად, იოლად მოცილებადი ადვილადდნობადი ან გაზური წიდის წარმოქმნით. მარტივი სამუშაო ციკლი, სტანდარტული აღჭურვილობისა და მოსამზადებელი ოპერაციების მინიმალური რაოდენობა უზრუნველყოფს მზურვალმედეგი შენადნობების ზედაპირების ეფექტურ და სტაბილურ გააქტიურებას 1000-1200°C ტემპერატურულ დიაპაზონში. ურთიერთქმედების პროცესების კვლევის საფუძველზე მზურვალმედეგ ნიკელის შენადნობ VZh-98-ზე (ქრომის მასური შემცველობით 26%-მდე) ცვეთამედეგი კომპოზიცია KBNHL-2-ის ზედაპირული გადადნობისას ნაჩვენებია, რომ აქტივატორის გამოყენება მნიშვნელოვნად ზრდის ზედაპირის ადჰეზიურ აქტივობას. დასველების კიდური კუთხეები იმყოფება მისაღებ 10-20° ფარგლებში და იოლად რეგულირდება ტემპერატურის ვიზუალური კონტროლის მეშვეობით. გაზური გარემოს გააქტიურების შეთავაზებული მოდელი შეიძლება გამოიყენებოდეს ლითონების დამუშავების, მათი დნობის, რჩილვის ან გაცხელების პროცესებში შედუღების წარმოებასა და მომიჯნავე ტექნოლოგიებში.

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