PRENOSNIKI TOPLOTE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Prenosniki toplote
Course title:	Heat Exchangers
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo - Razvojno raziskovalni program, druga stopnja, magistrski	Procesno strojništvo (smer)	2. letnik	1. semester	obvezni

Univerzitetna koda predmeta/University course code:	0566925
Koda učne enote na članici/UL Member course code:	6020-M

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30		30			65	5

Nosilec predmeta/Lecturer:	prof. dr. Iztok Golobič, prof. dr. Andrej Kitanovski, doc. dr. Katja Klinar, izr. prof. dr. Jože Kutin

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni strokovni predmet na smeri Procesno strojništvo, ki je izbirni strokovni predmet na ostalih smereh./Compulsory specialised course in the study of Process Engineering, which is an elective specialised course in other fields of study.

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Izpolnjevanje pogojev za vpis v Magistrski študijski program II. stopnje Strojništvo - Razvojno raziskovalni program.	Meeting the enrollment conditions for the Master's study programme of Mechanical Engineering - Research and Development program.

Vsebina:	**Content (Syllabus outline):**
1. Klasifikacija prenosnikov toplote - Glede na proces prenosa toplote, prenosniki toplote z indirektnim kontaktom, prenosniki toplote z direktnim kontaktom - Glede na število fluidov - Glede na kompaktnost površine (plin-kapljevina, kapljevina-kapljevina, fazna sprememba) - Glede na konstrukcijo (cevni prenosniki toplote, ploščni prenosniki toplote, razširjene površine, regeneratorji) - Glede na vrsto toka (z enim prehodom, z več prehodi) 2. Metode dimenzioniranja prenosnikov toplote - Eksaktne analitične metode, Aproksimacijske metode, Numerične metode,Ostale metode, - Toplotni in hidravlični preračun, konstruiranje, izdelava in stroški - Faktorji vpliva, Optimalni design - Učinek in učinkovitost prenosnika toplote, razmerje toplotnih kapacitet in število prenosnih enot - Epsilon-NTU razmerja, predstavitev metode LMTD, korekcijski faktor F, korekcijski faktorji za različne oblike toka 3. Posebnosti dimenzioniranja rekuperatorjev in regeneratorjev - Vzdolžna, prečna toplotna prevodnost, ali neuniformna toplotna prevodnost pri rekuperatorjih in regeneratorjih, - Posebnosti razširjenih površin - Posebnosti cevnih prenosnikov - Epsilon NTU0 metoda, Lambda-Pi metoda - Vpliv tlaka in cikličnega zadrževanja tekočin, - vpliva matrice in lastnosti materiala 4. Analiza padca tlaka - Glavni vzroki za padec tlaka, Predpostavke za analize - Padec tlaka pri razširjeni površinah, Padec tlaka v regeneratorjih - Padec tlaka v plošnih prenosnikih toplote - Padec tlaka v cevnih prenosnikih toplote - Padec tlaka in distribucija tekočin 5. Površina, materiali, geometrija prenosnikov toplote in neenaka distribucija tekočin - Cevni prenosniki toplote, Cevno-lamelni prenosniki toplote - Ploščni prenosniki toplote - Razširjene površine - Regeneratorji - Vpliv geometrije, Vpliv vstopnih in izstopnih kanalov, Vpliv karakteristik obratovanja, Rešitve 6. Izboljšan prenos toplote pri prenosnikih toplote - Pasivne, aktivne in sestavljene tehnike izboljšanega prenosa toplote, razvoj generacij tehnik izboljšanega prenosa toplote; - Izboljšan prenos toplote pri naravni in prisilni konvekciji brez in s fazno spremembo. 7. Uparjalniki	1. Classification of heat exchangers - With respect to the heat transfer process, indirect contact heat exchangers, direct contact heat exchangers - With respect to the type and number o fluids - With respect to the compactness of heat exchanger (gas-liquid, liquid-liquid, phase change) - With respect to construction (tube heat exchangers, plate heat exchangers, extended surfaces, regenerators) - With respect to the type of flow (single-pass, multi-pass) 2. Methods for dimensiong of heat exchangers - Exact analytical methods, Approximation methods, Numerical methods, Other types of methods - Thermal and hydraulical analysis, construction, manufacturing and costs - Influential factors, Optimal design - The effectiveness and efficiency of heat exchanger, capacity ration, NTU - Epsilon-NTU, introduction to the LMTD method, correction factor F, correction factors for different types o the flow 3. Spefics in dimensioning of recuperators and regenerators - Longitudinal, transverse thermal conductivity, non-uniform thermal conductivity in recuperators and regenerators, - Specifics of extended surfaces - Specifics of tube heat exchangers - Epsilon NTU0 method, Lambda-Pi method - The influence of pressure and cyclic maintenance of fluids, the influence of matrix and material properties. 4. Pressure drop analysis - Main causes for pressure drop, assumptions for analysis - Pressure drop in extended surfaces, Pressure drop in regenerators, - Pressure drop in plate heat exchangers - Pressure drop in tube heat exchangers - Pressure drop and fluid distribution 5. Surface, mateirals, geometry of heat exchangers, and fluid's maldistribution - Tube heat exchangers, finned coils - Plate heat exchangers - Extended surfaces - Regenerators - The influence of geometry, The influence of entrance and exit, The influence of operating parameters, Solutions 6. Enhanced heat transfer in heat exchangers - Passive, active, and combined techniques for enhanced heat transfer, and development of techniques for enhanced heat transfer; - Enhanced heat transfer for natural and forced

- Metode določevanja koeficienta toplotne prestopnosti ter kritične gostote toplotnega toka pri vrenju v bazenu, prisilnem konvektivnem vrenju v ceveh in vrenju v mikrokanalih; - Dimenzioniranje uparjalnika. 8. Prenosniki toplote s kondenzacijo - Metode določevanja koeficienta toplotne prestopnosti pri laminarni, laminarni valoviti in turbulentni filmski kondenzaciji ter kapljičasti kondenzaciji; - Dimenzioniranje kondenzatorja. 9. Toplotna cev - Toplotna cev in dvofazni zaprti termosifon, princip delovanja, vrste toplotnih cevi; - Omejitve v delovanju, toplotna karakteristika toplotne cevi, prenosnik toplote s toplotnimi cevmi, tehnologija izdelave. 10. Ploščni prenosniki toplote in prenos toplote v mikroelektronskih komponentah - Vizualizacija hidrodinamičnih tokov v ploščnem prenosniku in infrardeča termografija dinamike delovanja ploščnega prenosnika toplote; - Mehanizmi nastajanja oblog na površinah prenosnikov toplote; izboljšan prenos toplote v mikroelektronskih komponentah. 11. Tehnične zahteve za preskušanja prenosnikov toplote - Pregled tehničnih zahtev - Standardi in druga priporočila glede preskušanja prenosnikov - Izbira metod in postopkov preskušanja 12. Tlačni preskusi prenosnikov toplote - Tlačni preskusi in preskusi tesnosti: pregled metod - Merjenje pretoka puščanja po metodi tlačne spremembe, ugotavljanje netesnosti s helijevim detektorjem - Eksperimentalno določanje lastnih tlačnih izgub prenosnika 13. Merjenje pretoka tekočine in temperaturnega stanja v prenosniku toplote - Izhodišča merjenja pretoka tekočin, izbira ustrezne merilne metode - Izhodišča merjenja temperature in temperaturne razlike, izbira ustrezne merilne metode 14. Merjenje toplotnega toka, toplotne energije - Izhodišča merjenja toplotnega toka, toplotne energije - Izbira ustrezne merilne opreme - Merilno-tehnične zahteve in kontrola meroslovnih lastnosti 15. Določanje učinkovitosti prenosnikov toplote - Eksperimentalno določanje učinkovitosti prenosnika toplote - Dobre prakse glede izvedbe merilnega sistema - Vplivni dejavniki na kakovost meritve učinkovitosti prenosnika toplote	convenctions, with and without phase change. 7. Evaporators - Methods for definition of heat transfer coefficient and critical heat flux for pool boiling or evaporation, flow boiling or and evaporation in micro-channels; - Dimenzioniranje uparjalnika. 8. Condensers - Methods for definition of heat transfer coefficient for laminar, laminar-wavy, and turbulent film or droplets condensation; - Dimensioning of condenser. 9. Heat pipe - Heat pipe and two-phase closed thermosiphon, principle of operation, types of heat pipes; - Limitations in operation, thermal characteristics of heat pipes, heat pipe heat exchanger, manufacturing technologies. 10. Plate heat exchanger and heat transfer in micro-electronic components - Visualization of hydrodinamic fllows in plate heat exchangers and infrared thermography of dynamic operation of plate heat exchanger; - Mechanisms and fouling in heat exchangers; enhanced heat transfer in micro-elecronic components. 11. Technical requirements for testing of heat exchangers - Review of technical requirements - Standards and other recommendations regarding testing of heat exchangers - Selection of testing methods and procedures 12. Pressure testing of heat exchangers - Pressure testing and leak tightness testing: review of methods - Measurement of leak flow rate by pressure decay method, leak detection by helium detector - Experimetal determination of the exchanger's own pressure loss 13. Measurement of fluid flow rate and temperature conditions in heat exchanger - Fundamentals of flow rate measurement, selection of proper measurement method - Fundamentals of measurement of temeperature and temperature difference, selection of proper measurement method 14. Measurement of heat flow rate, thermal energy - Fundametals of measurement of heat flow rate, thermal energy - Selection of proper measurement equipment - Measurement-technical requirements and verification of metrological characteristics 15. Determination of heat exchanger efficiency - Experimental determination of heat exchanger efficiency - Best practices for realization of measurement system - Influence parameters on quality of measurements of heat exchanger efficiency

Temeljna literatura in viri/Readings:

Tropea, C., Yarin, A.L., Foss, J.F. (ur.): Springer handbook of experimental fluid mechanics. Springer, 2007 [COBISS.SI-ID 29032965]
VDI Gesellschaft, VDI Heat Atlas. 2nd Edition, Springer, 1993 [COBISS.SI-ID 1398555].
Baker, R. C.: Flow measurement handbook: industrial designs, operating principles, performance, and applications. Cambridge University Press, 2000 [COBISS.SI-ID 3809307]
Donatello Annaratone, Handbook for Heat Exchangers and Tube Banks design, 2010 [COBISS.SI-ID 1542724319]

Cilji in kompetence:

Cilji:

Cilj predmeta je podati študentu znanja s področja prenosnikov toplote na vseh področjih njihove uporabe. Z znanjem s področja prenosnikov toplote študent:

- pridobi temeljna znanja za obvladovanje dimenzioniranja in preračuna prenosnikov toplote;
- pridobi znanja za pravilno izbiro in vključitev prenosnikov toplote v procesne in energetske sisteme;
- pridobi sposobnosti, ki jih potrebuje za zniževanje rabe energije v procesni in energetski tehniki s pravilno izbiro prenosnikov toplote;
- pridobi sposobnosti, ki jih potrebuje za pravilno vzdrževanje sistemov z vgrajenimi prenosniki toplote;
- pridobi temeljna znanja glede načrtovanja eksperimentalnih preskušanj prenosnikov toplote;
- pridobi sposobnosti za načrtovanje merilnih sistemov za tlačne preskuse, preskuse tesnosti, določanje tlačnih izgub, določanje učinkovitosti prenosnika toplote.

Kompetence:

1. S1-MAG, P2-MAG, Razumevanje umestitve, delovanja in obratovalnih karakteristih prenosnikov toplote v procesni in energetski industriji. Sposobnost vključitve v širše delovne skupine za reševanje kompleksnih problemov na področju prenosnikov toplote v energetiki in procesni tehniki.
2. S2-MAG, S10-MAG, P5-MAG, Sposobnost samostojnega pridobivanja novih znanj in veščin.sposobnosti kritičnega, analitičnega in sintetičnega mišljenja pri zasnovi, analizi in dimenzioniranju prenosnikov toplote z razvojem novega znanja in razumevanja ter s

Objectives and competences:

Objectives:

The main objective of the subject is to provide student with knowledge in a domain of heat exchangers and their applications. With the knowledge obtained from the field of heat exchangers student will gain:

- basic knowledge for dimensioning and calculation analysis of heat exchangers;
- attain knowdlege for appriate selection and integration of heat exchanger in process and energy systems;
- attain abilities, which are needed for reduction of energy consumption in process and energy technologies, with the appropriate selection of heat exchangers;
- attain abilities, required for appropriate maintenance of systems with heat exchangers;
- attain basic knowledge on planning and design of experimental testing of heat exchangers;
- attain abilities for design of measurement systems for pressure testing, leak tightness testing, determination of pressure losses, and determination of heat exchanger efficiency.

Competences:

1. S1-MAG, P2-MAG, Knowledge and understanding problems for implementation, process and operation characteristics of heat exchangers in process and energy related industry. The ability to integration of a working group for solving complex problems in the field of heat exchangers in energy and process technologies.
2. S2-MAG, S10-MAG, P5-MAG, The ability of individual learning and gaining skills for critical, analytical, and synthetic thinking for analysis, dimensioning of heat exhcangers, with the ability for transfer of research results into practice..
3. S2-MAG, S7-MAG, P6-MAG, The ability to develop new knowledge with regard to the

sposobnostjo prenašanja rezultatov raziskav v prakso. 3. S2-MAG, S7-MAG, P6-MAG, Razvijanje novih znanj glede metodologije eksperimentalnega preskušanja prenosnikov toplote, usposobljenost za uporabo pridobljenih znanj pri načrtovanju s tem povezanih preskusnih sistemov in merilnih metod.	methodology of experimental testing of heat echangers, ability for knowledge transfer in design of experimental systems and measurement methods.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanja: Z2: Poglobljeno teoretično, metodološko in analitično znanje s področja prenosnikov toplote in njihovega preskušanja, ki je kot tako prenosljivo in dopolnjujoče z ostalimi disciplinami energetike in procesne industrije za kvalitetno delo na razvojno raziskovalnem in aplikativnem področju. Spretnosti: S2.1: Pridobitev prenosljivih spretnosti – niso vezane le na en predmet, in ki omogočajo sistematični pristop k obravnavi predmetne vsebine prenosnikov toplote. S2.3: Sposobnost izvirnih dognanj in kritične refleksije na področju procesnega in okoljskega inženirstva.	Knowledge: Z2: Deep theoretical, methodological, and analytical knowledge from the field of heat exchangers and their testing, which can be transferred and supplement to other domains of process industry for high quality basic and applied research. Skills: S2.1 : Attaining of transferrable skills – which are not related only to one subject – and which enable systematic approach in analysis of the subject from the field of heat exchangers. S2.3: Ability of unique inovations and critical reflections in the field of process and environmental engineering.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Klasične oblike poučevanja: • P1 Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov. • P3 Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri. • P4 Laboratorijske vaje z namenskimi didaktičnimi pripomočki (ploščni prenosnik toplote, prenosnik toplote cev v cevi, regenerator, križni prenosnik toplote, eksperimentalni sistemi za določanje tlačnih izgub, pretoka puščanja, toplotne učinkovitosti). • P5 Uporaba študijskega gradiva v obliki (zapiskov, e-verzija predstavitve predavanj). Moderne in prožne oblike poučevanja: • P6 Interaktivna predavanja • P8 Izdelava in predstavitev aplikativnih seminarskih nalog	Classical types of teaching: • P1 Auditorial lectures with solving of selected-for the domain specific – theroretical and practically applicable examples. • P3 Auditorial excercized, in which the theoretical knowledge is supported with numerical/analytical problems . • P4 Laboratory work with didactical means (plate heat exchanger, tube in tube heat exchanger, regenerators, cross-flow heat exchanger, experimental systems for determination of pressure losses, leakage flow rate and thermal effiiciency). • P5 The use of study material in the form of (lecture notes, e-version of lectures). Modern and flexible methods of teaching: • P6 Interactive lectures • P8 Applicative seminary work and its presentation

• P9 Skupinsko delo (razprave za – proti, razprave o prebranem, snežena kepa, strukturirana diskusija, viharjenje možganov, projektno delo,…) • P14 Virtualni eksperimenti • P15 Uporaba video vsebin kot priprava na predavanja in vaje	• P9 Team work (discussion for– against, discussions about read materials, snow-ball, structured discussion, brain-storming, project work,…) • P14 Virtual experiments • P15 The use of video materials in lectures and excercizes

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Teoretični del (predavanja).	50,00 %	Theoretical part (lectures).
Praktični del (vaje).	50,00 %	Practical part (exercises).
Ustni zagovor predloga ocene.		Oral examination of the proposed grade.

Ocenjevalna lestvica:	**Grading system:**
5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10	5 - 10, a student passes the exam if he is graded from 6 to 10

Reference nosilca/Lecturer's references:

Andrej Kitanovski:

1. RIJAVEC, Mojca, **KITANOVSKI, Andrej**, KLINAR, Katja. Design and analysis of 3D printed passive heat sinks. V: Akademija strojništva 2024 : inženirstvo - inovativen trajnostni razvoj z visoko dodano vrednostjo : Ljubljana, Cankarjev dom ter prek spleta, 10. december 2024. Ljubljana: Zveza strojnih inženirjev Slovenije - ZSIS, 2024. Letn. 13, št. 1/6, str. 62-63, ilustr. Svet strojništva, letn. 13, št. 1/6. ISSN 1855-6493. https://www.zveza-zsis.si/2024/11/30/svet-strojnistva-akademija-strojnistva-2024-december-2024/, DOI: 10.62020/svet.str.as2024010. [COBISS.SI-ID 222078979].
2. POREDOŠ, Primož, PETELIN, Nada, ŽEL, Tilen, VIDRIH, Boris, GATARIĆ, Pero, **KITANOVSKI, Andrej**. Performance of the condensation process for water vapour in the presence of a non-condensable gas on vertical plates and horizontal tubes. Energies. Apr. 2021, vol. 14, iss. 8, str. 1-28, ilustr. ISSN 1996-1073. https://www.mdpi.com/1996-1073/14/8/2291, DOI: 10.3390/en14082291. [COBISS.SI-ID 60378627].
3. MAIORINO, Angelo, DEL DUCA, Manuel Gesù, TOMC, Urban, TUŠEK, Jaka, **KITANOVSKI, Andrej**, APREA, Ciro. A numerical modelling of a multi-layer LaFeCoSi active magnetic regenerator by using artificial neural networks. Applied thermal engineering. Oct. 2021, vol. 197, str. 1-13, ilustr. ISSN 1359-4311. https://www.sciencedirect.com/science/article/pii/S1359431121008103?utm_campaign=STMJ_AUTH_SERV_PUBLISHED&utm_medium=email&utm_acid=104953246&SIS_ID=&dgcid=STMJ_AUTH_SERV_PUBLISHED&CMX_ID=&utm_in=DM168036&utm_source=AC_, DOI: 10.1016/j.applthermaleng.2021.117375. [COBISS.SI-ID 72137475].
4. POREDOŠ, Primož, PETELIN, Nada, VIDRIH, Boris, ŽEL, Tilen, MA, Qiuming, WANG, Ruzhu, **KITANOVSKI, Andrej**. Condensation of water vapor from humid air inside vertical channels formed by flat plates. iScience. [Online ed.]. Jan. 2022, vol. 25, iss. 1, str. 1-26, ilustr. ISSN 2589-0042. https://www.sciencedirect.com/science/article/pii/S2589004221015352?, DOI: 10.1016/j.isci.2021.103565. [COBISS.SI-ID 87969539].
5. **KITANOVSKI, Andrej** (avtor, vodja projekta), VIDRIH, Boris, POREDOŠ, Primož, LORBEK, Luka. Cyclic pressure testing of aluminum roll-bond heat exchangers. Ljubljana: Fakulteta za strojništvo, 2021. 2 zv. ([9] ; 10 f.), ilustr. [COBISS.SI-ID 55104259].

Iztok Golobič:

1. BERCE, Jure, ZUPANČIČ, Matevž, MOŽE, Matic, **GOLOBIČ, Iztok**. Infrared thermography observations of crystallization fouling in a plate heat exchanger. Applied thermal engineering. [Print

ed.]. Apr. 2023, vol. 224, str. 1-11, ilustr. ISSN 1359-431 DOI: 10.1016/j.applthermaleng.2023.120116. [COBISS.SI-ID 141882115].
2. BUCCI, Mattia, ZUPANČIČ, Matevž, GARIVALIS, Alekos Ioannis, SIELAFF, Axel, DI MARCO, Paolo, **GOLOBIČ, Iztok**. The role of the electric field in the departure of vapor bubbles in microgravity. Physics of fluids. Jan. 2023, vol. 35, iss. 1, str. 1-13, ilustr. ISSN 1070-6631. DOI: 10.1063/5.0127123. [COBISS.SI-ID 136576515].
3. RAZA, Md. Qaisar, KÖCKRITZ, Moritz von, SEBILLEAU, Julien, COLIN, Catherine, ZUPANČIČ, Matevž, BUCCI, Mattia, TROHA, Tadej, **GOLOBIČ, Iztok**. Coalescence-induced jumping of bubbles in shear flow in microgravity. Physics of fluids. Feb. 2023, vol. 35, iss. 2, str. 1-12, ilustr. ISSN 1070-6631. DOI: 10.1063/5.0138200. [COBISS.SI-ID 143706627].
4. ZAKŠEK, Peter, ZUPANČIČ, Matevž, GREGORČIČ, Peter, **GOLOBIČ, Iztok**. Investigation of nucleate pool boiling of saturated pure liquids and ethanol-water mixtures on smooth and laser-textured surfaces. Nanoscale and microscale thermophysical engineering. 2020, vol. 24, iss. 1, str. 29-42, ilustr. ISSN 1556-7265. DOI: 10.1080/15567265.2019.1689590. [COBISS.SI-ID 16891675].
5. **GOLOBIČ, Iztok**, ZUPANČIČ, Matevž, SEDMAK, Ivan, MOŽE, Matic, BERCE, Jure, BUCCI, Mattia, HADŽIĆ, Armin. Razvoj pametnih komponent toplotne postaje za projekt DOM 24h : zaključno poročilo. Ljubljana: Fakulteta za strojništvo, Laboratorij za toplotno tehniko, 2022. V, 44 f., graf. prikazi. [COBISS.SI-ID 105153795].

Jože Kutin:

1. ŽIBRET, Primož, BOBOVNIK, Gregor, **KUTIN, Jože**. Correction for the temperature effects in a pVTt gas flow primary standard employing a dynamic method. Measurement, Feb. 2023, vol. 207, str. 1-11. [COBISS.SI-ID 136867843].
2. RUPNIK, Klemen, BAJSIČ, Ivan, **KUTIN, Jože**. Modelling of a thermal dispersion mass flow meter. Flow measurement and instrumentation, 2018, vol. 59, str. 37-44 [COBISS.SI-ID 15793435].
3. BOBOVNIK, Gregor, **KUTIN, Jože**. Numerical study of the fluid-dynamic loading on pipes conveying fluid with a laminar velocity profile. Journal of fluids and structures. 2018, vol. 80, str. 441-450. [COBISS.SI-ID 16034587].
4. **KUTIN, Jože**, BOBOVNIK, Gregor, MOLE, Nikolaj, SCHAKEL, Menne D., BÜKER, Oliver. Measurement corrections for temperature effects in Coriolis mass flow meters for cryogenic, liquid hydrogen (LH2) applications. Measurement : journal of the International Measurement Confederation. [Print ed.]. Sep. 2024, vol. 237, [article no.] 115155, str. 1-13. [COBISS.SI-ID 200846339].
5. ŽIBRET, Primož, SPAZZINI, Pier Giorgio, BOBOVNIK, Gregor, **KUTIN, Jože**. Bilateral comparison of gas microflow primary standards in the range between 0.12 mg/min and 2.4 mg/min. Measurement. Sensors. 2025, vol. , no. , [article no.] 101588, 4 str. [COBISS.SI-ID 234746371].

Katja Klinar:

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