APPLICATION OF A CONTROL BANDING TOOL FOR RISK LEVEL ASSESSMENT AND CONTROL OF NANOPARTICLES EXPOSURE IN WELDING OPERATIONS

CONFERENCE PAPER · SEPTEMBER 2014

DOI: 10.13140/2.1.2798.4647

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APPLICATION OF A CONTROL BANDING TOOL FOR RISK LEVEL ASSESSMENT AND CONTROL OF NANOPARTICLES EXPOSURE IN WELDING OPERATIONS

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Porto, 26 Sept., 2014

Scope of study

- ✓ **Welding operations result in harmful emissions of nanoparticles** [1-2];
- ✓ **The aim of emissions monitorisation is to evaluate exposure levels and to derive protection measures in order to protect exposed workers;**
- ✓ **However, the traditional approach of comparing measured concentrations with exposure limits cannot be used;**
- ✓ **But risk levels can be quantified by using Control Banding Strategies [3];**

[1] Gomes et *al.*, J. Tox. Env. Health A., 75, 747/55 (2012)

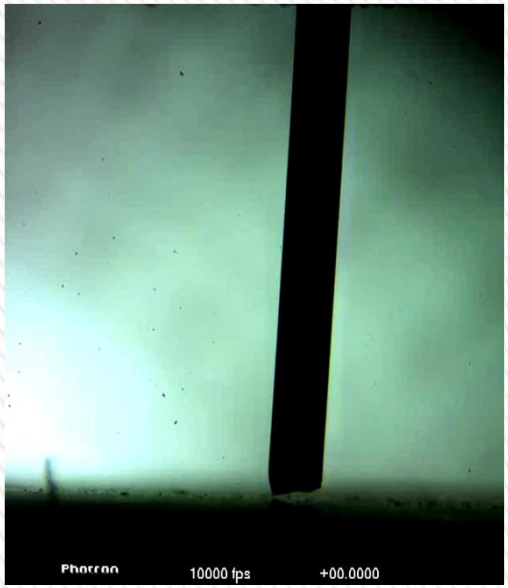
[2] Gomes et *al.*, Inh. Tox., 26, 345/52 (2014)

[3] Paik et *al.*, Ann. Occ. Hyg., 52, 419/28 (2008)

Welding process: MAG (metal active gas)

- ✓ **Uses an electric arc between wire filler material and plate to be welded, a gas protection mixture, and can proceed by three different electrical current transfer modes:**

Short-circuit



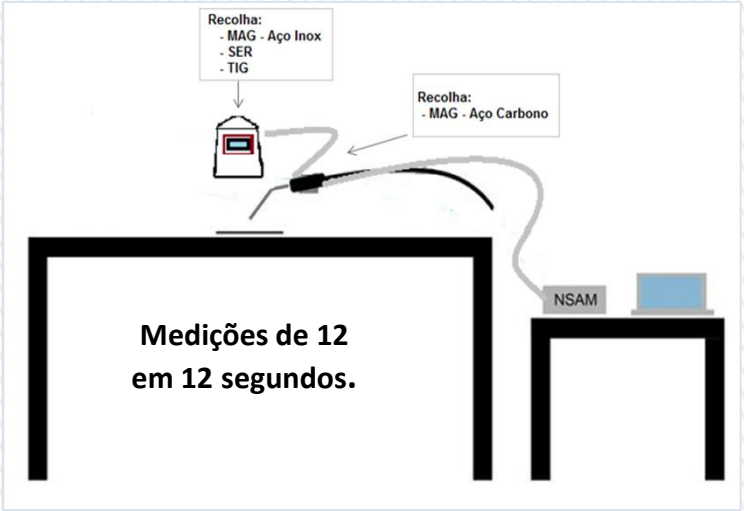
Globular

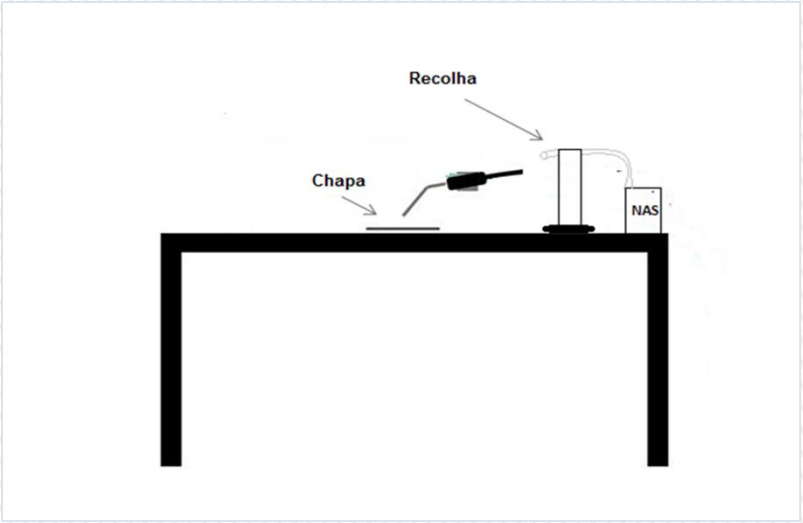
Spray

Exposure Assessment – MAG process

Monitoring equipment: NSAM

Working bench for welding



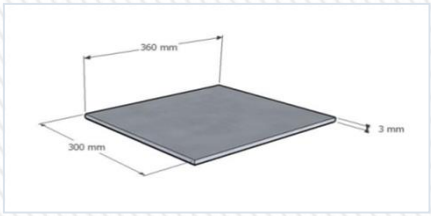


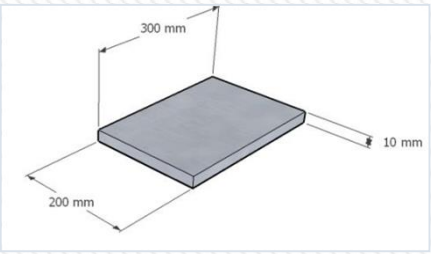
Sampling location during welding

Materials used for MAG welding

Chemical composition of steel plates

Steel plates	Chemical composition of base material (% weight)							
	C	Si	Mn	P	S	Cr	Ni	N
Mild steel	0,017	-	1,40	0,035	0,035	-	-	-
Stainless steel	≤ 0,08	≤ 1,00	≤ 2,00	0,045	0,030	8,0-10,5	18-20	0,10





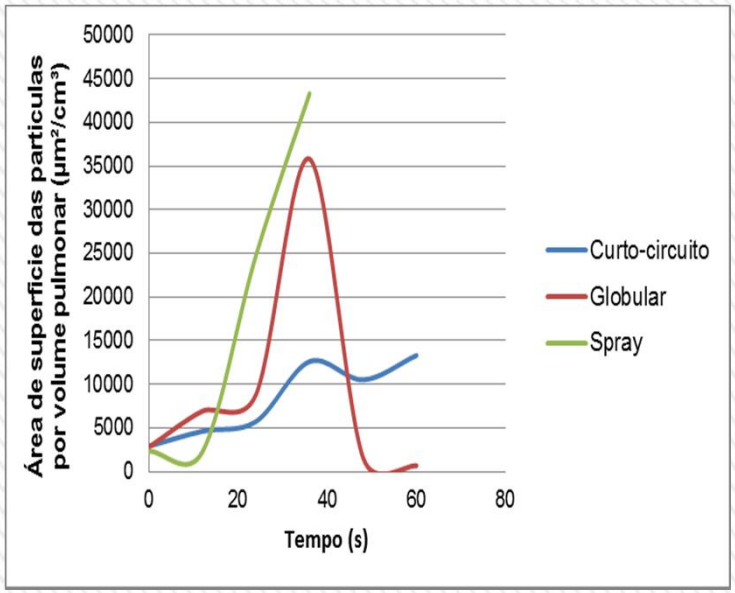
- ✓ **MAG** welding: using different wire filler materials ;
- ✓ **MAG** welding using different gas mixtures:

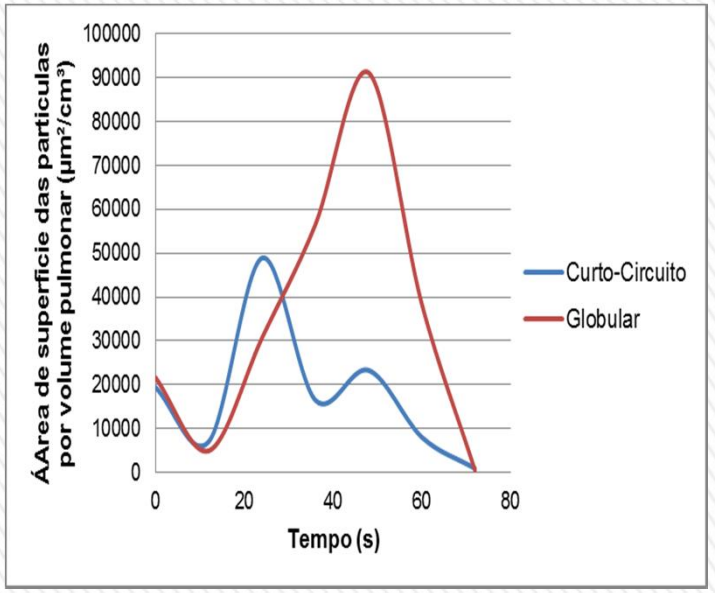
i) **mild steel**: Ar+10%CO_2 ; Ar+18%CO_2 ; 100% CO_2

ii) **stainless steel**: Ar+5%CO_2 ; 81%Ar+18%He+1%CO_2 ; 91%Ar+5%He+2%CO_2+2%N_2

- ✓ **Welding parameters**: different wire feeding velocities, different welding tensions and 3 different electric current transfer modes: globular, spray and short-circuit

MAG welding – NSAM results for mild steel



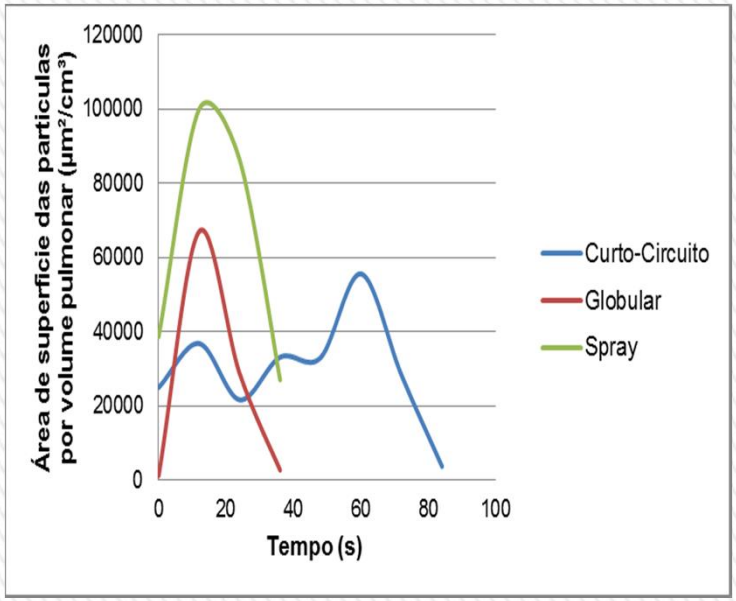


Nanoparticles as ADSA for ARCAL 21 (Ar+10%CO_2)

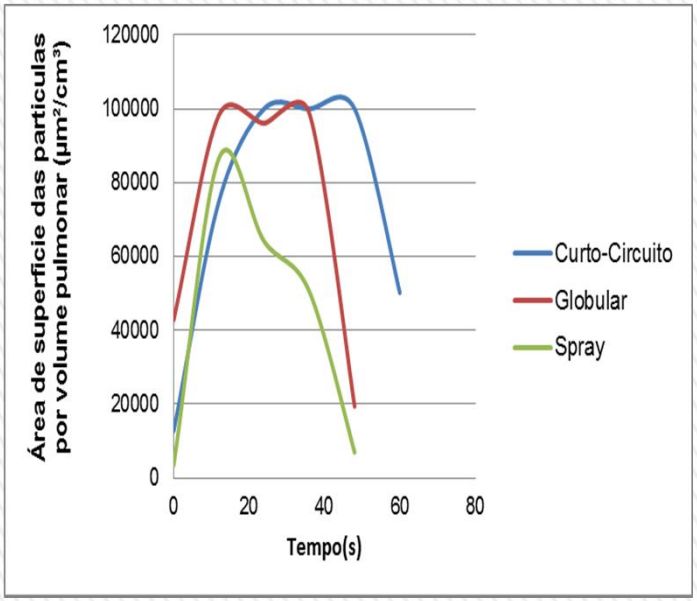
Nanoparticles as ADSA for ATAL 5 (Ar+18%CO_2)

Transfer mode	Average ADSA nanoparticles (µm²/cm³s)		
	Arcal 21	Atal 5	CO_2
Short- circuit	8 325	22 266	12 899
Globular	13 306	42 896	18 292
Spray	17 574	-	-

MAG welding – NSAM results for stainless steel



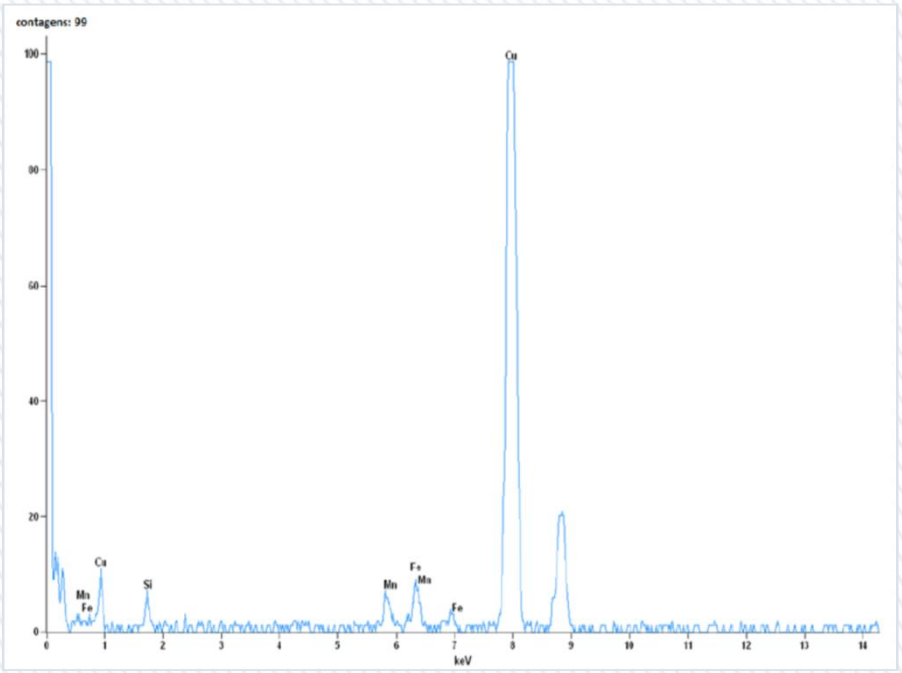
Nanoparticles as ADSA for ARCAL129 (91%Ar+5%He+2%CO_2+2%N_2)



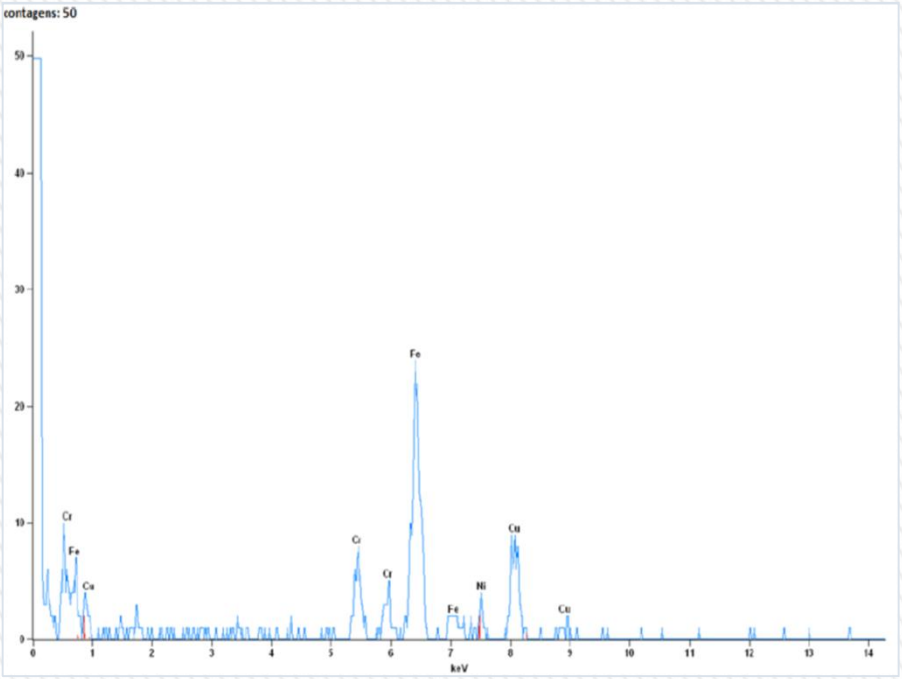
Nanoparticles as ADSA for ARCAL 121 (81%Ar+18%He+1%CO_2)

Transfer mode	Average ADSA nanoparticles (µm²/cm³s)		
	Arcal 12	Arcal 121	Arcal 129
Short-circuit	23 637	75 390	33 644
Globular	37 054	94 136	78 361
Spray	39 376	65 829	80 861

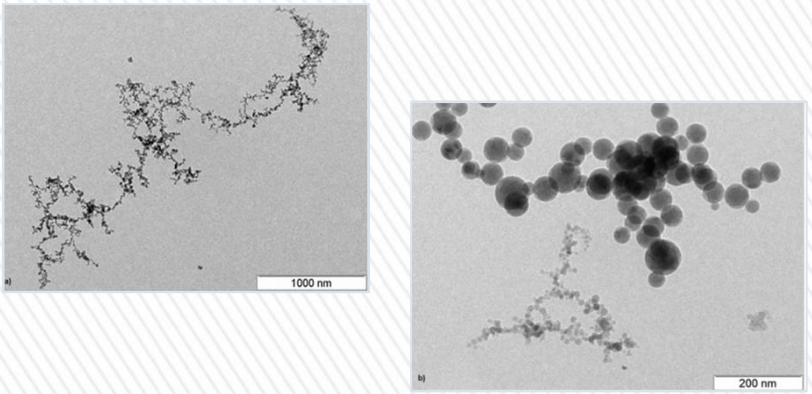
Nanoparticles characterisation - TEM and EDS



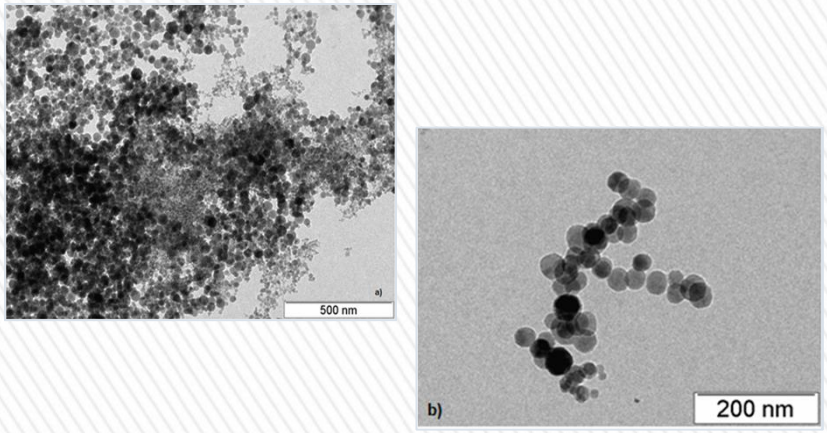
Nanoparticles EDS analysis for MAG welding: mild steel and ARCAL 21



Nanoparticles EDS analysis for MAG welding: stainless steel and ARCAL 129



Nanoparticles by TEM: mild steel



Nanoparticles by TEM: stainless steel

Risk assessment: *Control Banding Nanotool*

- ✓ NanoTool, was developed for qualitative risk assessment studies in order to control nanoparticle exposure.
- ✓ CB is a qualitative approach defining risk as equal to probability x severity and established adequate control measures.
- ✓ The tool considers several criteria:
  - **Punctuation for SEVERITY** (sum of all severity factors)**:**

0-25: Low severity ; 26-50: Medium severity ; 51-75: High severity ; 76-100: Very high severity.

Example:

- Å Nanoparticle shape: **Tubular or fibrous: 10 ; Irregular: 5 ; Compact or spheric: 0 ; Unknown: 7,5.**
- Å Carcinogenic material: **Yes: 6 ; No: 0 ; Unknown: 4.5.**

  - **Punctuation for PROBABILITY** (sum of all exposure factors):

0-25: Extremely unlikely ; 26-50: Less likely ; 51-75: Likely ; 76-100: Probable.

Example:

- Å Quantity of product used in each task:
  >100 mg: 25 ; 11-100 mg: 12.5 ; 0-10 mg: 6.25 ; Unknown: 18.75.
- Å Number of exposed workers:
  >15: 15 ; 11-15: 10 ; 6-10: 5 ; 1-5: 0 ; Unknown: 11.25.

Criteria punctuation using an Excel file

RL matrix as a function of severity and probablity [3]

		PROBABILITY			
		Extremely unlikely (0-25)	Less likely (26-50)	Likely (51-75)	Probable (76-100)
SEVERITY	Very High (76-100)	RL3	RL3	RL4	RL4
	High (51-75)	RL2	RL2	RL3	RL4
	Medium (26-50)	RL1	RL1	RL2	RL3
	Low (0-25)	RL1	RL1	RL1	RL2

Control bands:

RL 1 – General ventilation

RL 2 – Fume hoods or local exhaust ventilation

RL 3 – Containment

RL 4 – Seek specialist advice

[3] Paik et *al.*, Ann. Occ. Hyg., 52, 419/28 (2008)

Results of Risk Assessment

- ✓ **Risk assessment was based on three criteria**:
  - Nature of wire filler material ;
  - Gas protection of fusion pool, droplets of wire filler material and welding surface obtained thorugh the use of a gas protection mixture ;
  - Nature of base material (plate) to be welded.

- ✓ The description/classification of each material is based on Safety Material Data Sheets.
- ✓ **Base characteristics**: material description ; nanomaterial description ; CAS ; acitivity classification ; actual control engineering.

Results of risk assessment: MAG welding of mild steel using 100% CO_2

Activity	Severity	Probability	Total	Control band
1 (Wire filler material - Lincoln ER70S-6)	Medium (35)	Likely (57.5)	RL2 (125)	Fume hoods or local ventilation
2 (Gas protection)	Medium (30.5)	Likely (57.5)	RL2 (125)	Fume hoods or local ventilation
3 (Base material – Mild steel)	High (62.5)	Likely (55)	RL3 (150)	Containment

Factor having more influence in the implementation of control measures.

- ✓ **In what concerns MAG welding of mild steel, eficient control of nanoparticles emissions is obtained with the use of fume hoods or local ventilation as well as the use of containment measures.**

Good working practices

Preventive measures		
Workplace ventilation and localized exhaust/containment	**Utilization of Individual Protection Equipment**	**Analysis/selection of materials/processes/parameters leading to lower fume emissions**
- Take into consideration the general principles of the ventilation system: total welding time, factors associated with the emission rates, chemical composition of welding protection gas, fume extracted as close as possible of source, etc.	- Welding torch equiped with fume extraction system ; - Masks with embebed ventilation; - Improved welding torch design with the capability to collect more than 80% of emitted fume.	- Reduction of fume emissions at source: droplet source; electrode composition and gas mixture composition. - Diferent type of current (pulsed MAG). - Substitute conventional MAG welding for other processes: Surface Tension Transfer (STT), FastRoot and Cold Metal Transfer (CMT).
- Ventilation systems: local (fume extracted directly from welding surface) or general. - Operations organisation in order to optimise pollutant extraction efficiency.	- Allow to increase significantly the mobility of welding processes, as welding operations are not dependant from na extraction system difficult to handle.	- Use protection gases having low content of active gases (thus reducing the oxidizing potential).

Placement of suction device just above fume emission source

Rotating extraction arm suspended in order to cover a wide area of a welding workshop

Portable filtration system

Welding torch with embebed fume extraction system

Conclusions

Welding processes, such as MAG, do produce considerable nanoparticle emissions which are potential harmful for exposed workers.

As traditional risk assessment is difficult to perform due to the inexistence of exposure limit values, control banding is an alternative to perform actual risk assessment and to derive protection measures.

However, this approach is qualitative and somewhat general.

Nevertheless, it can direct to protection measures such as exaust hoods and local ventilation as well as containment.

One should always keep in mind that, the adoption of good working practices, must take into account the feasibility (both technological and economical) of altering the welding conditions.

Thanks for listening !!!

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