PIPELINE SAFETY
INSTITUTE

DOT Pipeline Compliance Workshop

Lesson 13 - Corrosion Control

(Presentation Handouts)

Pipeline Safety Institute – Your one-stop destination for understanding pipeline compliance. Whether you are new to the industry, an experienced oil & gas professional that needs a refresher, or you want to take a deep dive into the latest regulation changes, you are at the right place.

Training topics cover pipeline operations and engineering concepts, with future course offerings for Integrity Management programs, including In-line inspection, material testing, fitting and component selection, and qualifying welders. Our curriculum continues to grow to meet the changes and challenges in the energy industry.

The Pipeline Safety Institute has a team of experienced trainers and subject matter experts from all disciplines. With over 25 years of training experience, we are committed to providing the best pipeline safety training in the industry.

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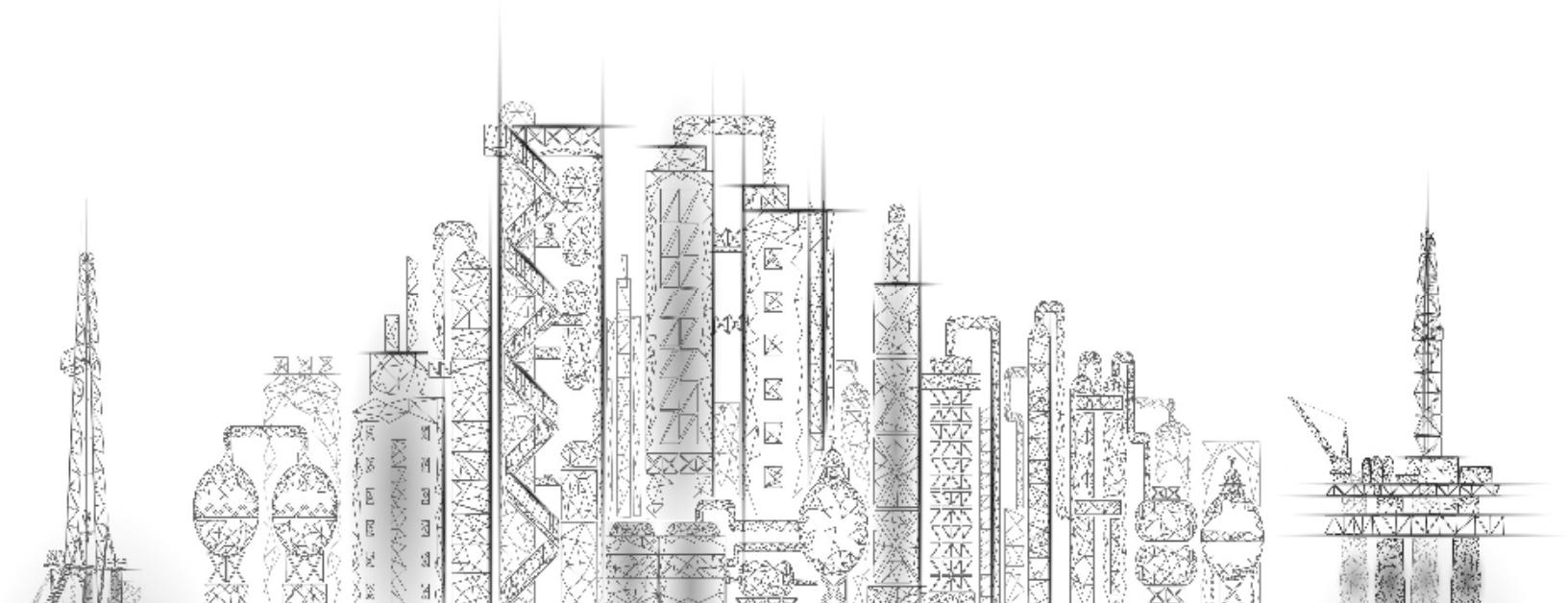
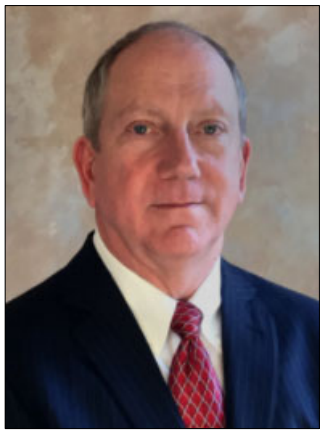


Trainers

Our trainers have a wealth of industry experience working with regulatory agencies and knowledge of DOT regulations. They provide participants with a practical perspective on their implementation at a level all can understand.



W. R. (Bill) Byrd, PE

President

RCP Inc.

As founder and principal of RCP Inc., Mr. Byrd enjoys a solid reputation for working with the public, corporate executives, legal representatives, and regulatory agencies to resolve complex regulatory, integrity management, safety, and compliance management issues. He combines exceptional analytical and communication skills with a broad background in engineering, operations, management, economics, and regulatory affairs, yielding excellent professional judgment and capabilities that can be applied to intractable problems. He is a widely respected public speaker and is routinely called upon to make presentations to industry associations and other groups at the national level. He is a licensed Professional Engineer in four states and graduated with honors from Georgia Institute of Technology for his M.S. and B.S. in Mechanical Engineering.

Chris Foley, CSP

Vice President

RCP Inc.

Chris Foley has a deep understanding of the new gas transmission and gathering regulations, including participating in the Joint Industry Trade Association Task Group to prepare for and submit comments throughout the Gas Pipeline Advisory Committee process. Mr. Foley owns three patents for MaxOp, which is widely considered the gold standard used across the gas and hazardous liquid pipeline industry for MAOP validation. He serves on the ANSI GPTC Z380 Gas Piping Technology Committee and the American Gas Association Engineering Committee. Mr. Foley has almost 30 years of experience developing and implementing engineering and regulatory compliance solutions and technology for the oil and gas industry. He earned a Bachelor of Science in Industrial Engineering with a specialty in Systems Safety Engineering from Texas A&M University.


Lesson 13
Corrosion Control

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Lesson 13 : Topic 1
Types of Corrosion

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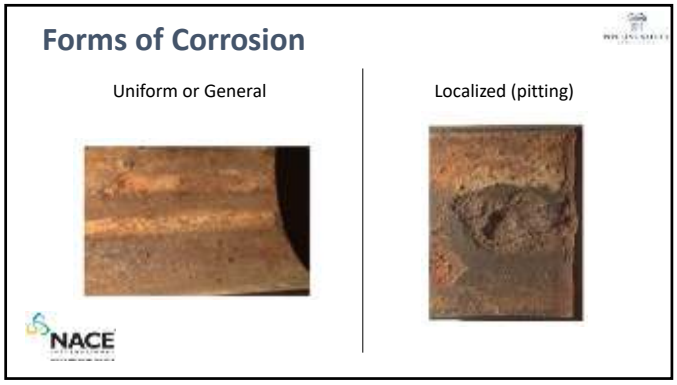
Forms of Corrosion
Uniform or General
Localized (pitting)
NACE

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Microbiological Influenced Corrosion (MIC) a.k.a. "Bugs"

Pipe Rupture Due To MIC

Fluorescent Microscopic Examination of Bacteria Colony on Pipe

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Stress Corrosion Cracking (SCC)

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AC Corrosion

Pitting - Leak

Nodule on Pipe

- Capacitive Couple
- Inductive Couple
- Conductive Couple

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Pipeline Coatings

Coal Tar Enamel Coating

Fusion-Bonded Epoxy (FBE) Coating

3-Layer Polypropylene Coating

Extruded Polyethylene Coatings

Polyethylene Tape-Wrap

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External Corrosion: Coating Monitoring §192.461(c) /§195.561

Effective coating is first line of defense

- But coatings can be damaged during and after construction

Prior to lowering -

- Must inspect pipe coating just prior to lowering / submerging pipe and backfilling (a.k.a. "jeeping")
- Repair any discovered damage

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Cathodic Protection for External Corrosion Control

- Use cathodic protection to prevent corrosion at "holidays" or spots where coating is damaged
- Cathodic protection makes the pipeline a cathode so that corrosion is mitigated
- Two types:
  - Galvanic (sacrificial anodes)
  - Impressed current (rectifiers)

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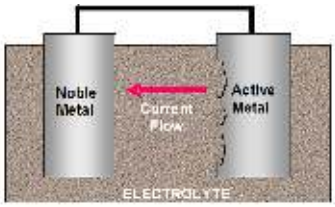
Galvanic Corrosion Cell

Potato batteries are not about the potato!



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Galvanic Series (Sacrificial Anodes)

Metal	Volts vs. Cu-$CuSO_4$	Volts vs. Ag-AgCl
	Active or Anodic End	Active or Anodic End
Magnesium	−1.60 to −1.75	−1.55 to −1.70
Zinc	−1.10	−1.05
Aluminum	−1.05	−1.00
Clean Carbon Steel	−0.50 to −0.80	−0.45 to −0.75
Rusted Carbon Steel	−0.30 to −0.50	−0.25 to −0.45
Cast/Ductile Iron	−0.50	−0.45
Lead	−0.50	−0.45
Steel in Concrete	−0.20	−0.15
Copper	−0.20	−0.15
High Silicon Iron	−0.20	−0.15
Carbon, Graphite	+0.30	+0.35
	Noble or Cathodic End	Noble or Cathodic End

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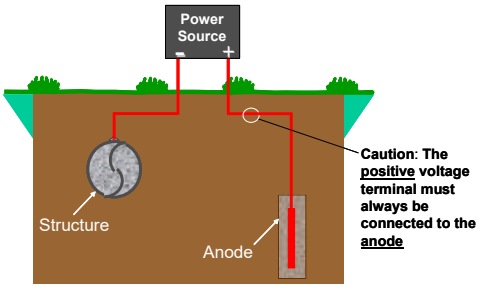
Impressed Current CP



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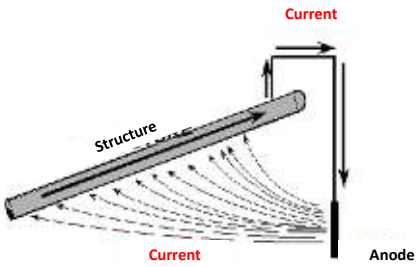
Impressed Current CP



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Typical Rectifier Setup

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Cathodic Protection (CP) Systems

Sacrificial Anodes	Impressed Current Anodes
Current requirements are low	Current requirements are high
Soil resistivity is low (<10,000 ohm-cm)	Soil resistivity is high (>10,000 ohm-cm)
Electrical power is not available	Electrical power is readily available
Relatively limited lifetime protection	Long life protection is required

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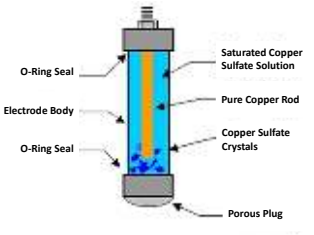
Pipe to Soil (P/S) Readings



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Remote Monitoring Test Station

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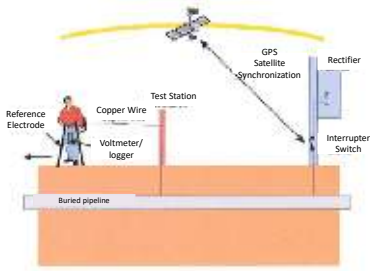
Close-Interval-Survey (CIS)



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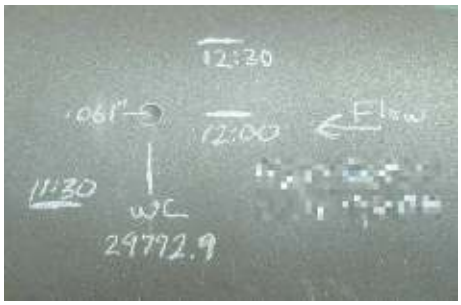
CP Interference / Poor Bonding



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Consequences of Incorrect Connections

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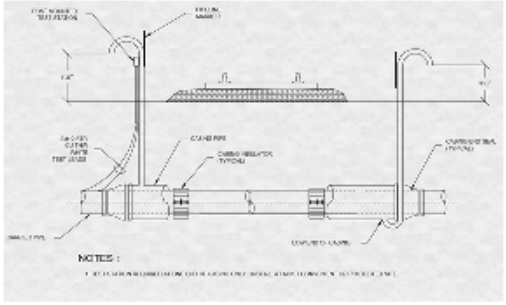
Pipe in Casings



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Cathodic Protection Videos

Spectra Energy CP video:

https://www.youtube.com/watch?v=PPTBZXlvBS4&feature=c4-overview-vl&list=PLDA8614CF092492BA

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Gas Cathodic Protection (CP) Systems

§192.457 Pipelines installed before August 1, 1971

- If pipe is effectively externally coated, it must have CP installed
  - Coating not considered effective if CP current requirements are same as bare pipe
- Areas where active corrosion found must have CP
  - Bare or ineffectively coated transmission lines
  - Bare or coated piping at compressor, regulator, & measuring stations
  - Bare or coated distribution lines

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Gas Cathodic Protection (CP) Systems

§192.455 Pipelines installed after July 31, 1971

- Must have effective external coating and have CP system operational within 1 year of construction completion, unless
  - Demonstrate via tests, investigation, or experience that a corrosive environment does not exist
  - Close interval pipe-to-soil tests must be completed w/in 6 months to validate no corrosive environment exists
- All pipe that is externally coated must have CP

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Liquid Cathodic Protection (CP) Systems

§195.557 Pipelines installed, relocated, replaced after March 31, 1970 (interstate liquid pipeline), July 31, 1977 (interstate offshore liquid gathering), October 20, 1985 (intrastate liquid pipeline), July 11, 1991 (CO_2 pipeline), or August 10, 1994 (low stress pipeline)

- Must have effective external coating and have CP system operational within 1 year of construction completion

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Cathodic Protection (CP) – Unprotected Systems

- **§192.465 / §195.573(b)**: electrical survey every 3 years, not to exceed 39 months for presence of active corrosion
  - Areas with active corrosion must be protected
- Where CIS is impractical, can determine areas of active corrosion by other means (leak history, exposed pipe reports, CP monitoring records)

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Cathodic Protection (CP) Monitoring

- **§192.465 / §195.573** CP systems must be inspected as follows
  - Pipe-to-Soil surveys annually not exceeding 15 months
  - Rectifiers 6 times/year, not exceeding 2 ½ months
  - Critical bonds 6 times/year, not exceeding 2 ½ months
  - Non-critical bonds annually not exceeding 15 months
- Liquid: Breakout tanks **§195.573(d)**
  - Inspect CP system if necessary, under 195.402(c)(3)

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Liquid External Corrosion Monitoring

Protected pipelines **§195.573(a)**

- Determine if close interval surveys are necessary to meet NACE SP0169-2007, Section 10.1.1.3

Where practicable and determined necessary by sound engineering practice, a detailed (close-interval) potential survey should be conducted to:

- ✓ (a) assess the effectiveness of the cathodic protection system;
- ✓ (b) provide base line operating data;
- ✓ (c) locate areas of inadequate protection levels;
- ✓ (d) identify locations likely to be adversely affected by construction, stray currents, or other unusual environmental conditions; or
- ✓ (e) select areas to be monitored periodically.

NACE - National Association of Corrosion Engineers

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Internal Corrosion Monitoring

§192.475 / §192.477 / §195.579 Internal Corrosion

- Investigate corrosive effect of product being transported.
- If corrosive products being transported
  - Monitor effectiveness of inhibitors with coupons
  - Inspect coupons 2 times/year not exceeding 7 ½ months
  - Liquid: Use inhibitors in sufficient quantity & quality
- Inspect internal pipe surface when pipe is removed

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Internal Corrosion - Prevention

- Maintenance pigging (remove sludge)
- Biocides (maybe batch between pigs)
- Corrosion Inhibitors (continuous or batched)
  - Basically, trial and error on what and how much
- Oxygen scavengers
  - Only a few parts per million can cause problems
- Dehydration (gas, especially if Carbon-di-oxide involved)
- Liquid water removal / drains
- Dead leg elimination / flushing

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Gas Internal Corrosion – Design & Construction Requirements

New and replaced gas transmission pipelines, effective May 23, 2007, must:

- Be configured to reduce the risk that liquids will collect in the line
- Have effective liquid removal features
- Allow use of corrosion monitoring devices in locations with significant potential for internal corrosion

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Atmospheric Corrosion Monitoring

- **§192.481 / §195.583 Atmospheric Corrosion**
  - Inspect above ground sections as follows
    - ONSHORE 1 time every 3 years, not exceeding 39 months
    - OFFSHORE annual not exceeding 15 months
- **Pay attention to:**
  - Pipe at soil-to-air interfaces,
  - Areas under thermal insulation and disbonded coatings
  - Areas at pipe supports, and deck penetrations
  - Pipe in splash zones and over-water pipe
- ASTM D610 - 08(2012) Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces

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External Corrosion: Random Examination / Documentation

§192.459/ §195.569

Pipe exposed by excavation – examine each exposure for

- Coating deterioration / external corrosion
- If found, search circumferentially and longitudinally via visual or indirect examination to determine whether remedial actions are necessary

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Corrosion Control Records

§192.491/ §195.589

- Must maintain records or maps with location of:
  - Cathodically protected pipelines
  - Cathodic protection facilities (i.e., rectifiers, test leads)
  - Galvanic anodes (number & spacing)
  - Bonded structures
- Monitoring records retained at least 5 years
- The following monitoring records must be maintained for the life of the system
  - Close interval surveys for no CP systems
  - Annual pipe-to-soil surveys
  - Internal surface inspections and coupons
  - Inspections of buried pipe when exposed (liquid)

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External Corrosion Evaluation

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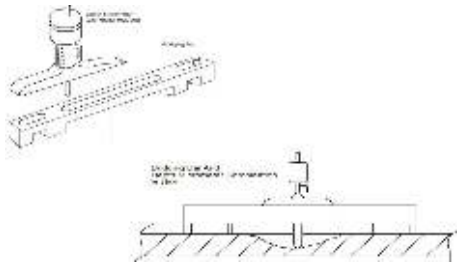
Traditional Measurement of Metal Loss



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Corrosion Repairs / Remedial Actions

Localized Corrosion Pitting / Generalized Corrosion

- Strength of pipe must be established if repairs do not include cylinder replacement via
  - ASME/ANSI B31G
    - Modified Battelle
    - RSTRENG
  - LPC-1
  - Shell92
  - PCORRC
- Replace affected cylinder
- Reduce pressure commensurate w/remaining wall thickness
- Repair methods w/reliable engineering tests to permanently restore serviceability of pipe

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Lesson 13 : Topic 8

PHMSA Guidance

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PHMSA Enforcement Guidance

- Supervisor qualification (Gas): operator must state how they define a qualified person for corrosion (e.g., PE or NACE certified).
- If you stop testing at a particular station, you must justify that testing at that station is no longer necessary and document it.
- Should have remedial action started within a few months, less if required monitoring is < 1 year or if could be an immediate hazard to the public. Correct problems before next scheduled monitoring.

PHMSA - Pipeline and Hazardous Materials Safety Administration

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PHMSA Enforcement Guidance

- History of no internal corrosion is not proof that the product being transported is not corrosive. Corrosion coupon records provide only a localized indication of corrosion and do not satisfy the requirement to investigate the corrosive effect of the product
- Oxidation (or "light surface oxide") is not atmospheric corrosion because there is no evidence of metal loss

PHMSA - Pipeline and Hazardous Materials Safety Administration

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PHMSA Enforcement Guidance

Examples of Probable Violations

- Rectifier that was not operating for 20 months but another rectifier 3 miles away was OK and P/S readings were OK. The rectifier still needed to be fixed within a reasonable time.
- Difficult site conditions, permits, or lack of electrical power are not a valid excuses for "prompt remedial actions" requirement.
- Remediation timeframes should be defined in O&M Manual. These time frames should consider the consequences of a release.

PHMSA - Pipeline and Hazardous Materials Safety Administration; O&M – Operation & Maintenance

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Corrosion Under Insulation (CUI)

ADB-2016-04

- Buried, insulated pipelines must have coatings and CP systems that protect against CP shielding
- Difficult to address CUI with conventional CP systems
- Review O&M and integrity management activities to ensure that CUI is adequately addressed
- See also:
  - NACE International publication 10A392, 2006 Edition, "'Effectiveness of Cathodic Protection on Thermally Insulated Underground Metallic Structures,'
  - API Standard 1163, ''In-Line Inspection Systems Qualification Standard'' 2nd edition, April 2013, (API Std. 1163)

O&M – Operation & Maintenance

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