# Feature and Benefit of UNS S34752, Advanced 347AP material "NEXAGE™ 347AlPha" For High Temperature Application as Alternative of Type 347H

## 1. Background

It is well known that the conventional stainless steels such as Type 316L, Type 317L, Type 321(H) and Type 347(H) have risk of PTA-SCC (PolyThionic Acid Stress Corrosion Cracking) and SRC (Stress Relaxation Cracking) occurrence in Hydrotreating units, Hydrocracking units and Delayed Coker units of petroleum refineries. PTA-SCC is caused by the combination of 3 factors: formation of PTA due to exposure the metal sulfide scale to oxygen and water in the aqueous phase, residual tensile stress and sensitized microstructure having the Cr carbide precipitation at the grain boundary. Therefore, NACE SP0170-2018 provides the following mitigation methods to protect conventional stainless steels from PTA-SCC[1)].

(1) For mitigation of formation of Polythionic acid

- Alkaline washing of equipment surfaces to neutralize Polythionic acid
- Nitrogen purging to exclude oxygen and water which is a source of Polythionic acid
- Air drying to prevent from liquid water formation

(2) For minimizing sensitization of stainless steel

- Application of stabilized stainless steel (Type 321, Type 347 etc)
- Stabilization heat treatment after welding (around 900 deg. C for 4 hours)

(3) For reduction of residual stresses

- PWHT (Post Weld Heat Treatment)

As new PTA-SCC mitigation method to save cost, NIPPON STEEL proposes AP (Anti-PTA-SCC) series austenitic stainless steels as New Metallurgy to PTA-SCC solution for all petroleum refineries. Table 1 shows the summary of AP series developed by NIPPON STEEL. The remarkable characteristic of AP series is excellent PTA-SCC resistance without PWHT and/or thermal stabilization. These properties are achieved by extreme low C up to 0.02% and higher Nb/C ratio over 15 to prevent $M_{23}C_6$ precipitation at grain boundary of HAZ (Heat Affected Zone) during welding.

Table 1. Target Application and Properties of AP series Austenitic Stainless Steel

| Application | Conventional Stainless | AP Series | Standard | PTA-SCC Resistance | SRC Resistance | NAC** Resistance | Max. Design Temperature |
|---|---|---|---|---|---|---|---|
| CDU*<br>VDU* | Type 316L<br>Type 317L | **NEXAGE™ 317AP** | UNS S31740 | Good | - | Good | 593 deg.C<br>(1100 deg. F) |
| Hydrotreater<br>Hydrocracker | Type 321(H)<br>Type 347(H) | **347AP** | UNS S34751<br>ASME CC2196 | Good | Good | - | 675 deg.C<br>(1250 deg. F) |
| Delayed Coker | Type 347H | **NEXAGE™ 347AlPha** | UNS S34752<br>ASME CC2984 | Good | Good | - | 816 deg.C<br>(1500 deg. F) |

*CDU; Crude Distillation Unit, VDU; Vacuum Distillation Unit
**NAC; Naphthenic Acid Corrosion


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## 2. Characteristics of NEXAGE™ 347AlPha

### 2-1. Chemical Composition

Table 2 shows the typical chemical composition range of NEXAGE™ 347AlPha compared with 347AP, Type 347LN (UNS No. S34751) and Type 347H (UNS No. S34709).
347AP is the distinctive version of Type 347LN to improve PTA-SCC resistance by fine tuning of the chemical composition within the range of Type 347LN. The characteristics of 347AP is extreme low C content and Nb addition under higher Nb/C ratio to prevent the sensitization by precipitation of $M_{23}C_6$ carbide at grain boundaries and higher N content to improve the tensile and creep properties at elevated temperature.
Furthermore, in order to achieve much higher creep strength than 347AP, Cu, Mo and B are added to 347AP and fine chemical tuning is also conducted. Then, NEXAGE™ 347AlPha (Low C-18Cr-11Ni-3Cu-Mo-Nb-B-N) chemical contents are finalized as shown in Table 2.

Table 2. Chemical composition (mass%)

| Item | C | Si | Mn | Cr | Ni | N | Nb | Cu | Mo | B |
|---|---|---|---|---|---|---|---|---|---|---|
| **NEXAGE™ 347AlPha** | 0.005 -0.02 | Max. 0.60 | Max. 2.00 | 17.0 -19.0 | 10.0 -13.0 | 0.06 -0.12 | 0.20-0.50 | 2.50 -3.50 | 0.20 -1.20 | 0.001 -0.005 |
| 347AP | 0.007 | 0.36 | 1.48 | 17.2 | 10. | 0.08 | 0.31 | | | |
| Type 347LN (S34751) | 0.005 -0.020 | Max. 1.00 | Max. 2.00 | 17.0 -19.0 | 9.0 -13.0 | 0.06 -0.10 | 0.20-0.50 (Min. 15 x C) | | | |
| Type 347H (S34709) | 0.04 -0.10 | Max. 0.75 | Max. 2.00 | 17.0 -19.0 | 9.0 -13.0 | - | Min. 10 x C | | | |

### 2-2. Sensitization Resistance

Figure 1 shows microstructure of NEXAGE™ 347AlPha and Type347H aged at 600 °C for 1,000 hours which is the result of ASTM A262 Practice A.
Dual structures can be observed in NEXAGE™ 347AlPha. On the other hand, Type 347H shows ditch structure due to the precipitation of $M_{23}C_6$ at grain boundaries. These results suggest that NEXAGE™ 347AlPha has higher sensitization resistance than Type 347H.

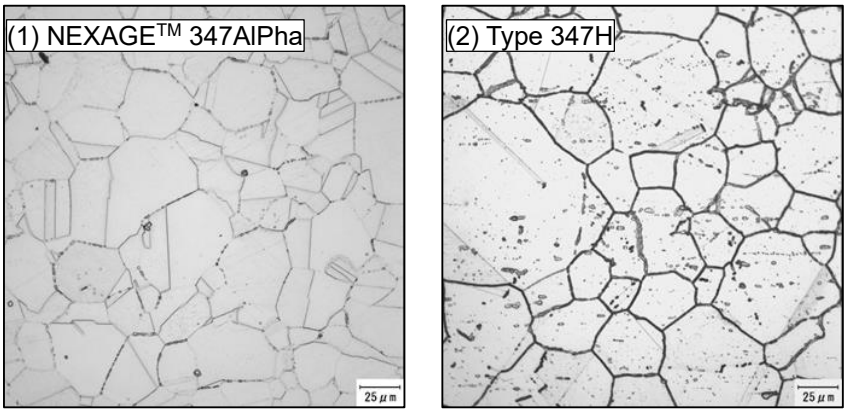



Figure 1.Microstructure after 1,000-hour aging at 600 °C, followed by etching in accordance with ASTM A262 Practice A.


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## 2-3. PTA-SCC Resistance

PTA-SCC test results are shown in Figure 2. Type 347H shows PTA-SCC after 300-hour aging at 600 °C. On the other hand, NEXAGE™ 347AlPha shows no PTA-SCC even after long-term aging up to 10,000 hours in the temperature range from 600 to 700 °C.

[Test Condition]

| | |
| --- | --- |
| Method | Hosoya, Yamamoto and Kagawa's method[3)] |
| Solution | 1% $K_2S_4O_6$, pH=2.0 (acidified by $H_2SO_4$) |
| Temp. | Room Temp. |
| Duration | 100 hours |

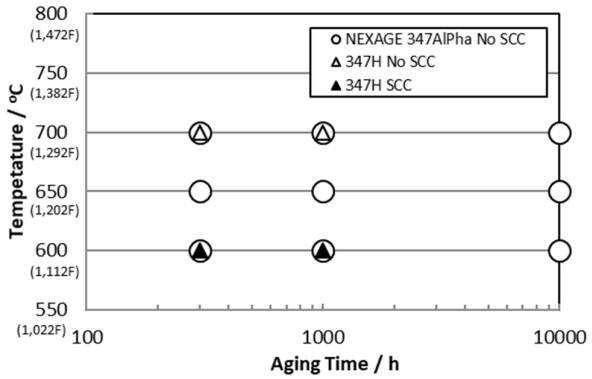



Figure 2. PTA-SCC Test Results

## 2-4. Creep Property at high temperature

The maximum allowable tensile stress of NEXAGE™ 347AlPha is estimated as shown in Figure 3 compared with that of the conventional materials. NEXAGE™ 347AlPha shows more than 30% higher maximum allowable tensile stress at the temperatures where creep properties control the stresses compared to that of Type 347H and 347AP.

This is because of fine copper rich phase and Z-phase (NbCrN) precipitates as shown in Figure 4.

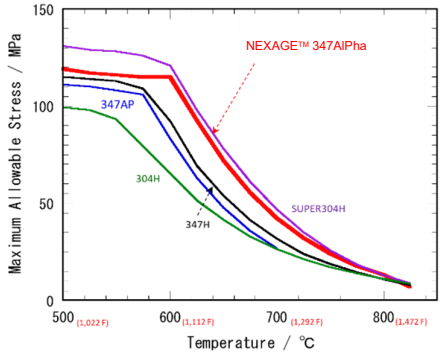



Figure 3. Comparison of Maximum Allowable Tensile Stress

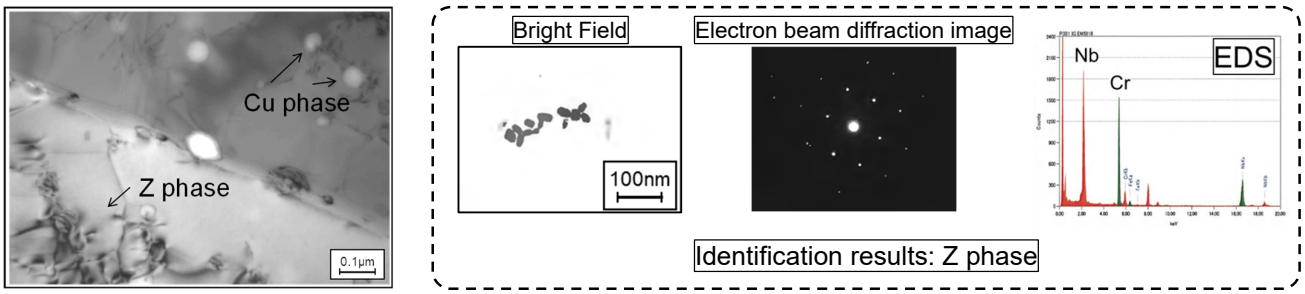



Figure 4. TEM image of NEXAGE™ 347AlPha (ruptured specimen at 700 °C/1,292 °F for 2,363 hours)



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### 2-5. SRC Resistance [4]

SRC test condition and results are as shown in Table 3 & Figure 5. NEXAGE™ 347AlPha shows no fracture even after 1,000 hours passed under 10% strain. On the other hand, Type 347H is fractured shortly under 5% strain.
Based on these results, NEXAGE™ 347AlPha also has better SRC resistance than Type 347H.

Table 3. SRC Test Condition

| No. | Process | Condition |
| --- | --- | --- |
| 1 | Heat Treatment to simulate Heat Affected Zone | 1300 deg.C for 3 minutes |
| 2 | Pre-Strain | 10% at RT |
| 3 | SRC Test at 650 deg.C | Hot Plastic Strain; 10% for Advanced 347AP<br>5% for Type 347H<br>Test Duration; Max. 1,000 hours |

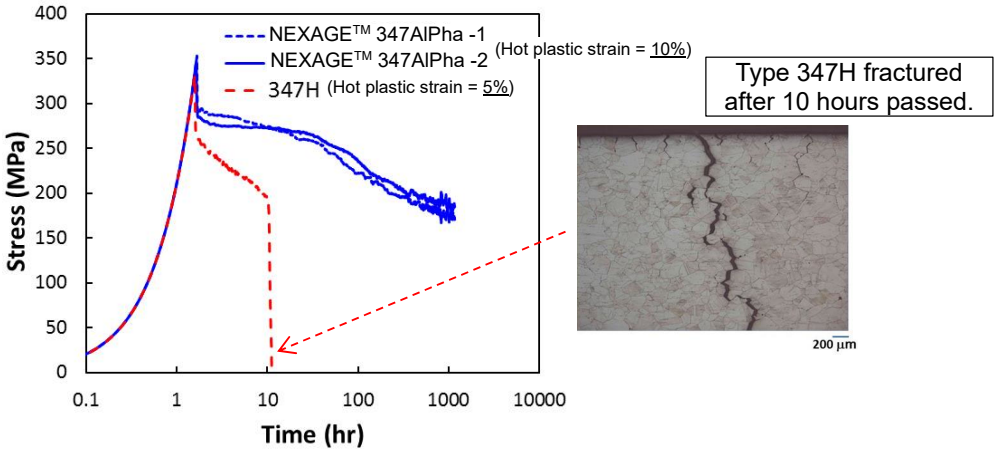



Figure 5.Relaxation test results

### 2-6. Weldability

Matching filler of NEXAGE™ 347AlPha has already been developed.

### 2-7. Standardization

NEXAGE™ 347AlPha had been registered in ASTM A213 and A312 as UNS S34752, same as ASME Code Case 2984. This grade is also approved for API530 in 2021 and will be reflected in next version or addendum.

## 3. Benefit

Applying AP series is beneficial to save fabrication and turnaround operation costs.

In terms of fabrication, PWHT and thermal stabilization heat treatment like 1650ºF (900°C) for four hours is not required for AP series.
Also, regarding turnaround operation, conventional mitigation method for PTA-SCC such as neutralization using soda ash and nitrogen sealing can be eliminated.

In addition, wall thickness can be reduced because of higher allowable tensile stress than Type 347H.

Thus, AP series can make big benefit, especially for fabrication and operation.


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## 4. Contact

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## 5. References

1) NACE SP0170, “Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During a Shutdown of Refinery Equipment”, NACE International, Houston, TX.

2) T. Osuki, M. Seto, H. Okada, M. Sagara, S. Matsumoto and T. Ono : ASME PVP Conference 2017, PVP2017-65536 Proceedings.

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4) Y. Suzuki, T. Osuki, M. Ueyama, E. Dan, N. Otaki and H. Okada : NACE Corrosion 2021, NACE 2021-16636 Proceedings.

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