
『2022 KEPIC Week』

DLN 연소기 가스터빈의 Class별 미연 배출물질 변화상태와 저감방안 고찰

2022. 7.15

한국동서발전(주)

기술전문연구센터

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결론

◎ 사회적 측면

- 가스터빈 발전소는 대부분 도시 인근에 설치되어 생활과 밀접한 관계
- 에너지 전환에 따른 가스터빈 복합발전소 역할의 중요성 부각
- 오염물질 배출과 건강에 관련한 환경문제에 관심 증가

* 언론 보도사례(한국경제신문)

‘친환경’ LNG 발전소의 배신... 알고 보니 유해물질 대량 배출(2019. 4. 7)

불완전 연소는 발전소를 다시 켜는 시점에 저온연소와 화염불안정으로 발생

LNG 발전소 전국에 24개 모두 배출

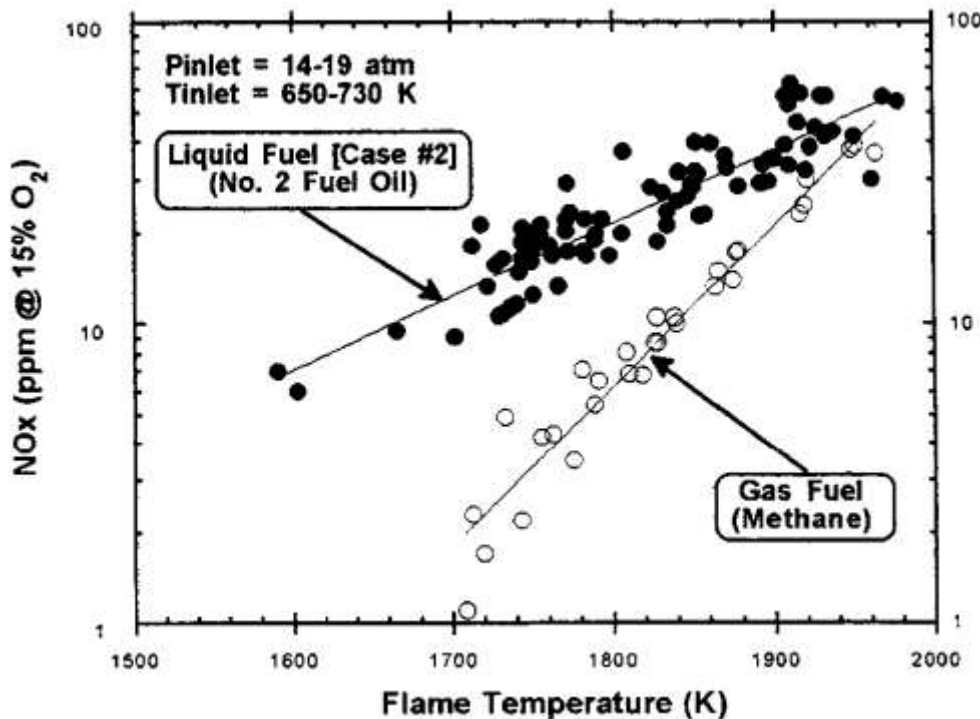
최대 CO 2000ppm, UHC(Unburned Hydrocarbon) 7000ppm

◎ 학술적 측면

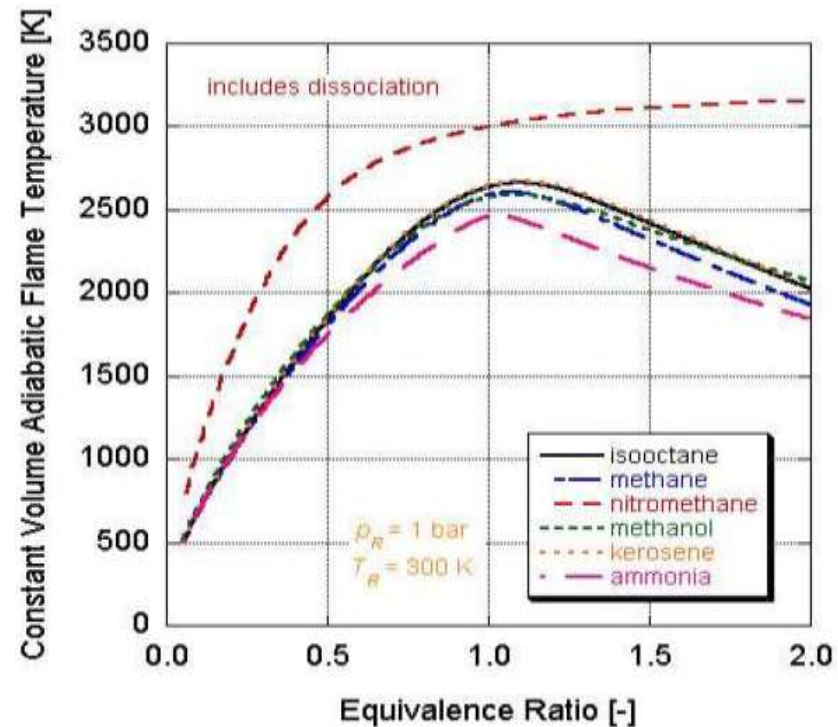
- 가스터빈 기동 초기에 발생하는 CO와 UHC 관련 연구사례 거의 없음

◎ 질소산화물(NOx)

- 연소영역의 온도가 높은(확산화염, 고출력) 상태에서 발생농도 증가



[가스터빈 연소온도에 따른 NOx 발생-ASME)



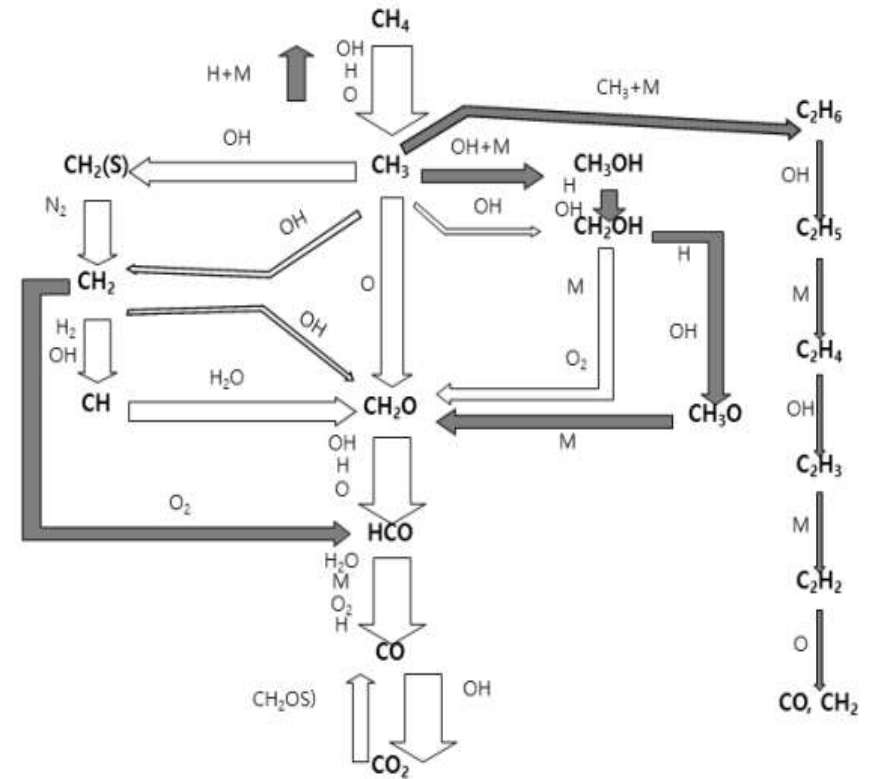
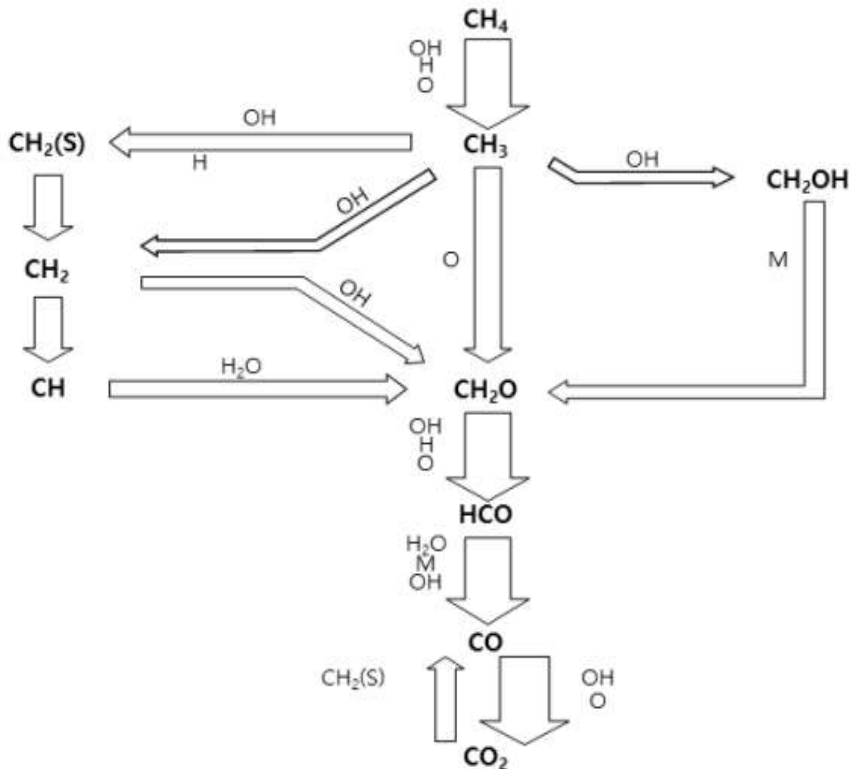
[연료별 당량비에 따른 연소온도 변화)

II.

이론적 배경

미연탄화수소(UHC), 일산화탄소(CO)

- 낮은 연소온도 영역에서 UHC/CO 발생함



CH_4 combustion mechanism with high temperature condition (2200K) CH_4 combustion mechanism with low temperature condition (<1500K)

◎ 미연탄화수소(UHC), 일산화탄소(CO)

- 연료희박 영역에 UHC/CO 발생이 많고, HC=>CO=>CO₂ 분해과정을 거침

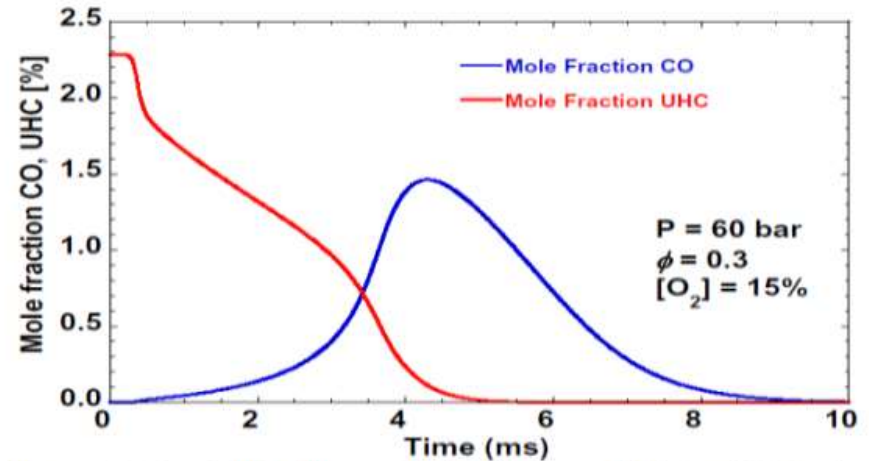
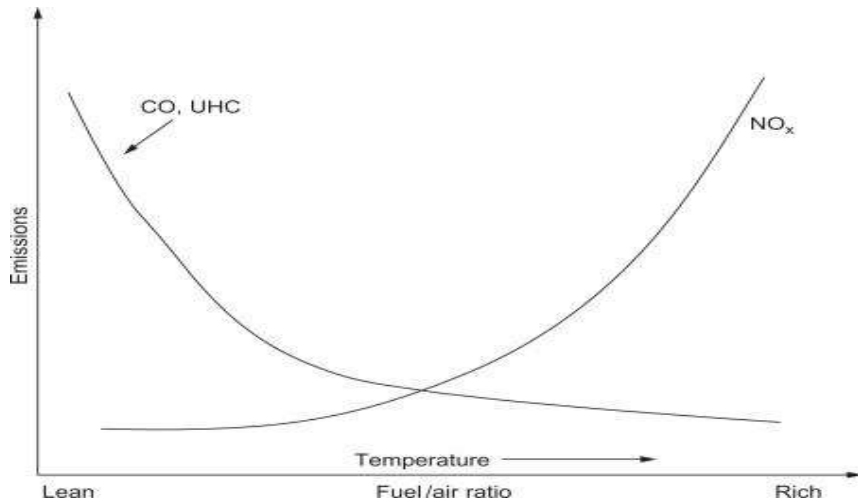


Figure 32. Constant volume oxidation history of UHC and CO of a $\phi = 0.3$ mixture in a 60 bar, 15% [O₂] atmosphere.

[연소온도에 따른 대기배출물질 변화¹⁾]

[UHC*, CO 산화반응 시간²⁾]

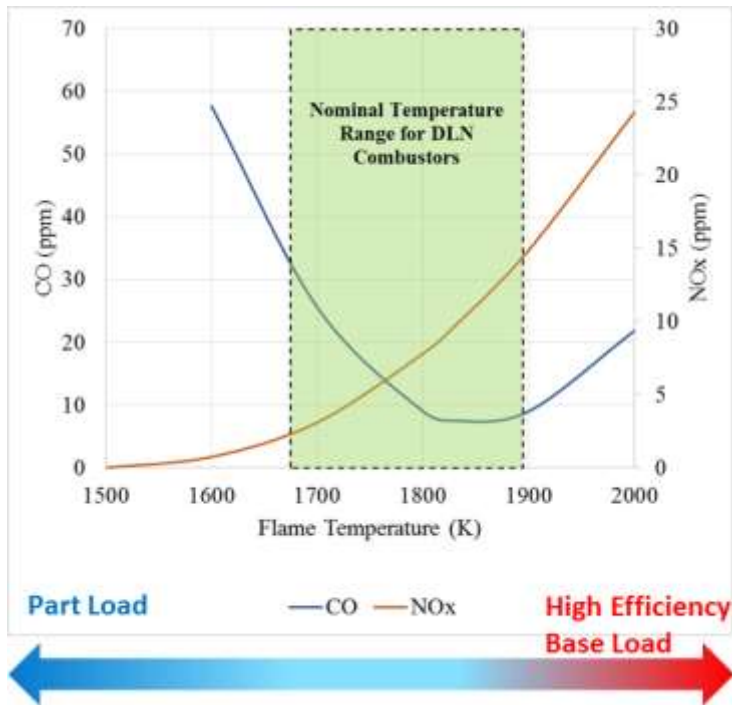
1) Gas Turbine Engineering Hand Book

2) Effect of Intake Pressure on Performance and Emission in an Automotive Diesel Engine Operation in Low Temperature Combustion Regimes

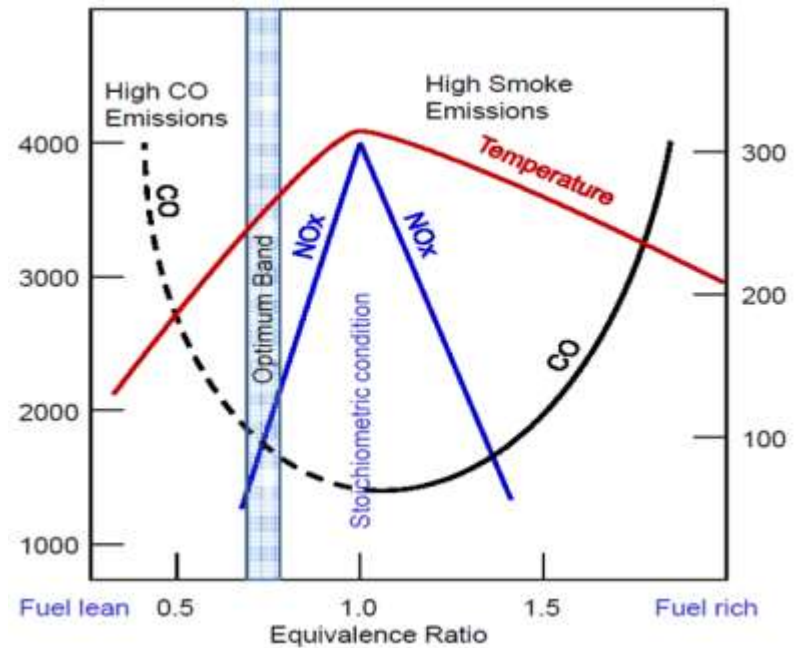
* UHC(Unburned Hydrocarbon)인데 THC와 동일하게 미연탄화수소를 지칭함

NOx - CO/UHC 상관관계

- UHC/CO와 NOx 발생량은 반대의 관계임



[가스터빈 DLN 연소기 NOx-CO 발생관계(EPRI)]



[당량비와 NOx-CO 상관관계]
*발전용가스터빈 p142(경문사, 이병은)

Ⅲ.

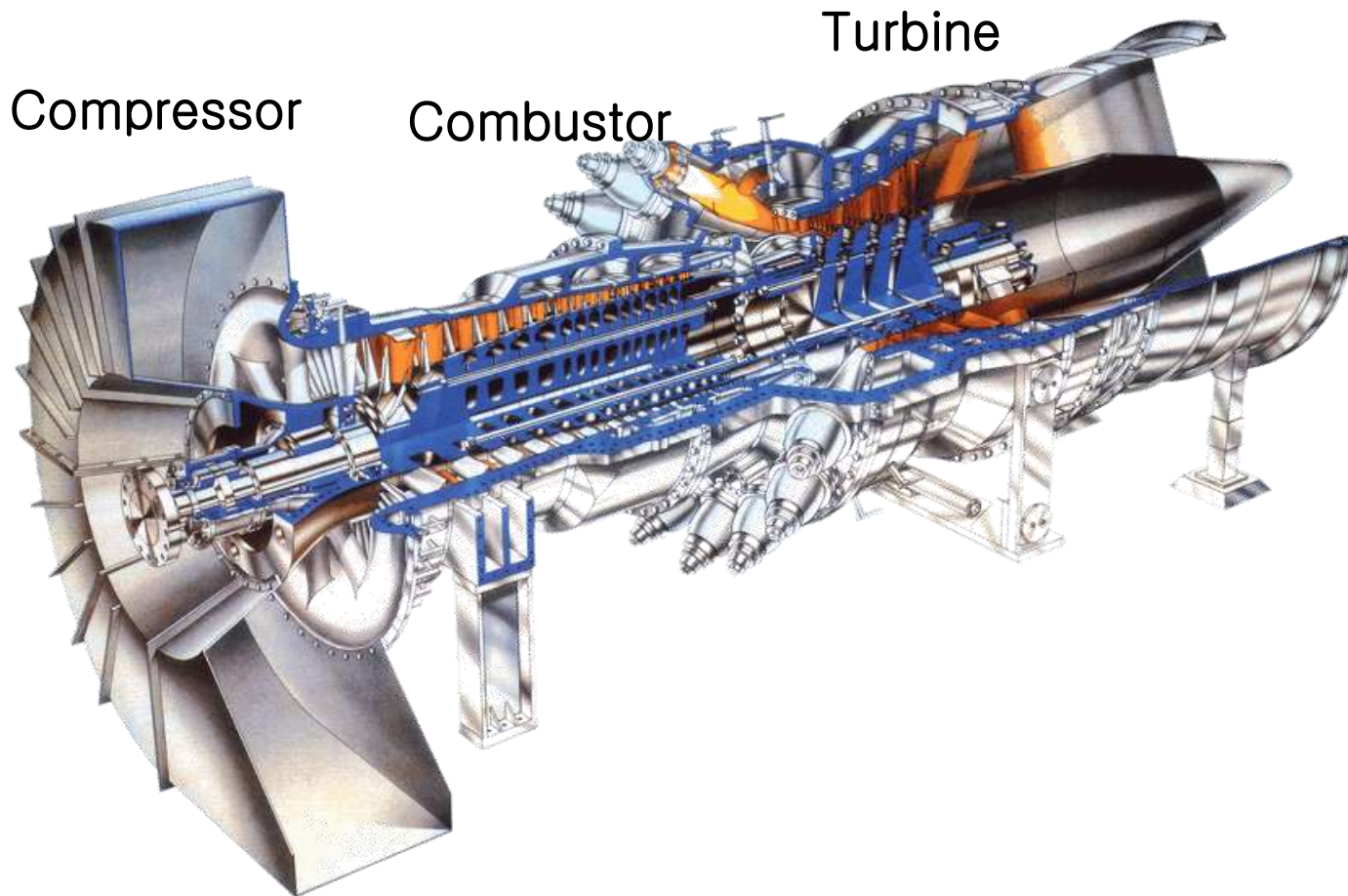
실험대상 및 측정방법

- ◎ 대상설비 : DLN 복합화염 연소기 적용 가스터빈
 - 100MW W501D5 / 160MW W501F / 320MW M501J
- ◎ 측정방법 : 연료비율/연소공기 조정, 1분단위로 측정
 - NO_x : 대기오염공정시험방법, 15% O₂
 - UHC : 화염이온화 감지법
(FID, flame ionization detection)
 - CO : 비분산적외선 흡수방식
(NDIR, non-dispersive infrared)

Ⅲ.

실험대상

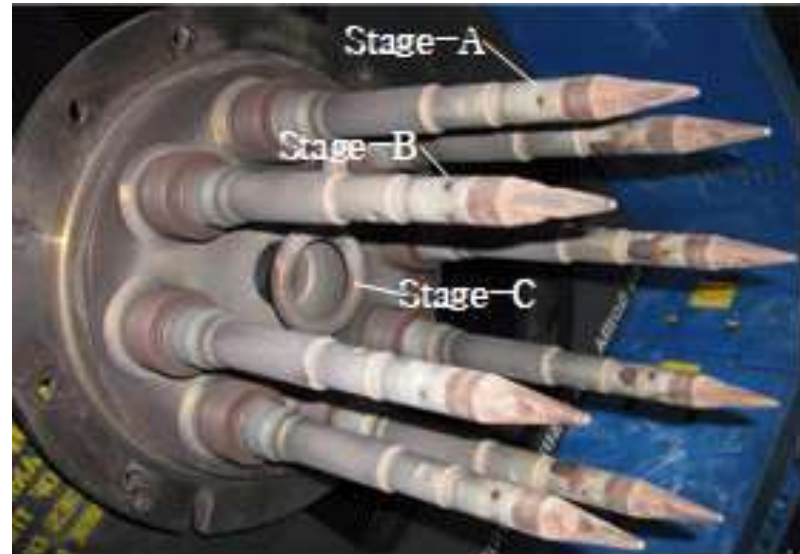
◎ 가스터빈 : 천연가스 등을 연소, 에너지 생산



III.

실험대상(W501D5/F)

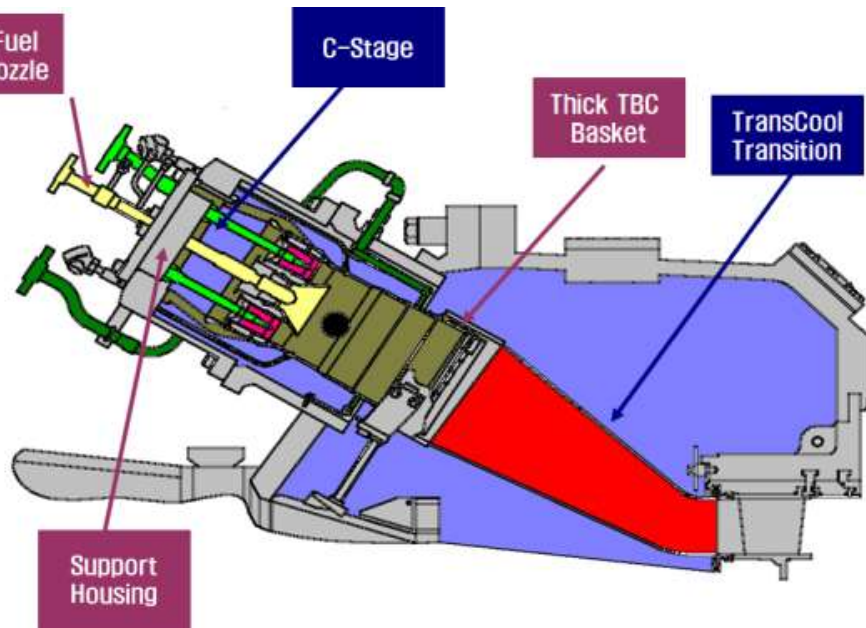
W501D5 DLN 연소기 구성 : P/A/B/C-stage



Stage-A/B/C nozzle of DLN combustor



Pilot nozzle of DLN combustor



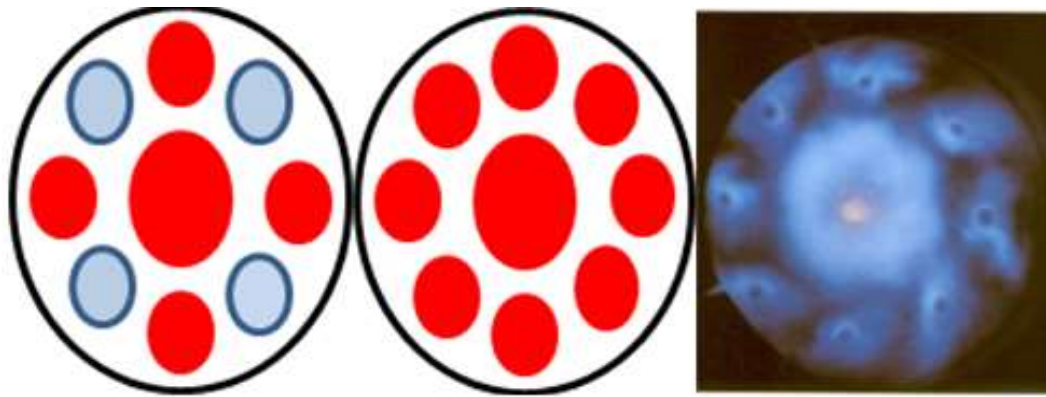
Schematic diagram of gas turbine combustor

W501F DLN 연소기 구성 : C-stage 없음

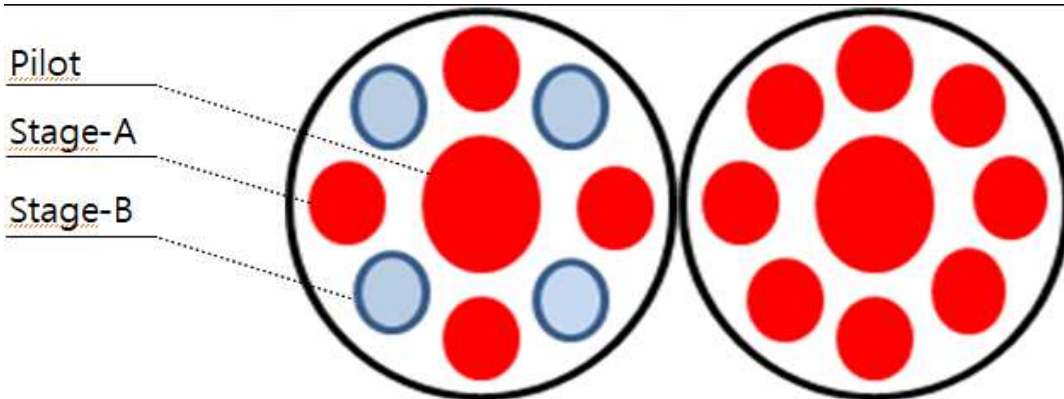
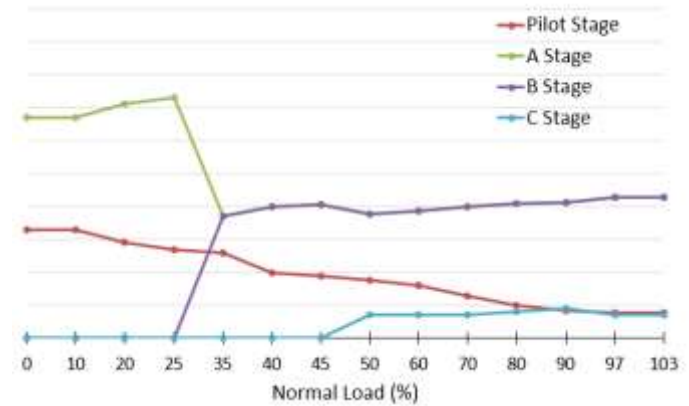
III.

실험대상(W501D5/F)

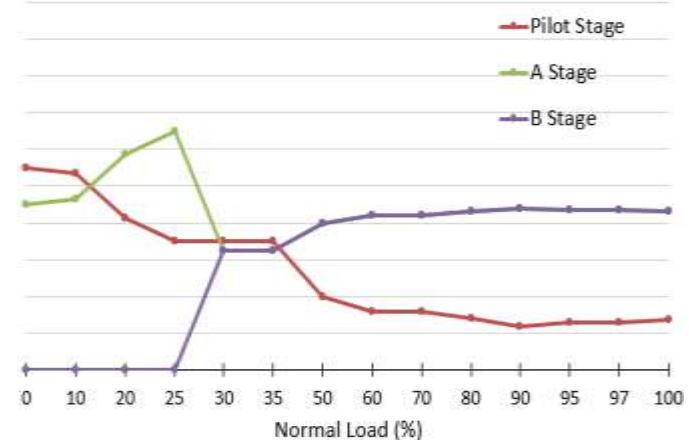
가스터빈 W501D5/W501F DLN 연소기 운전



Firing~30% load 30~50% load Base load



점화~35% load 35%~100% load

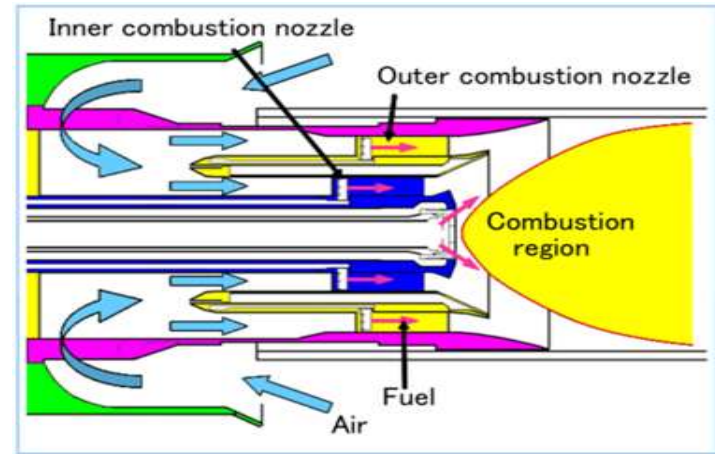
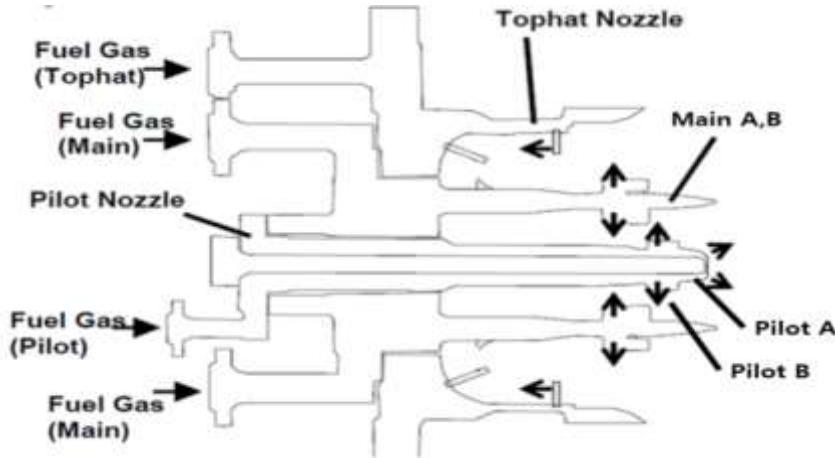


[W501D5/W501F 가스터빈 출력별 화염형상]

III.

실험대상(M501J)

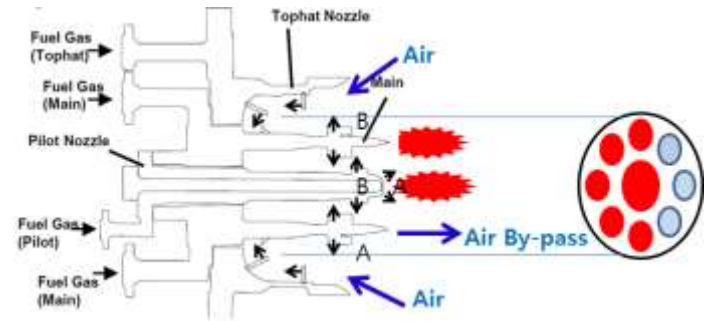
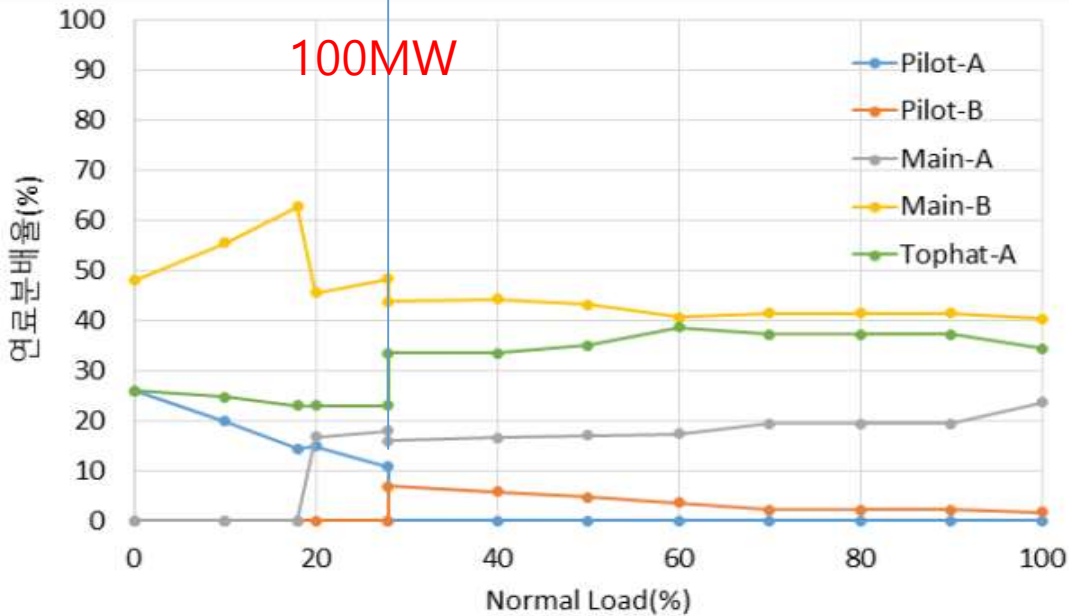
◎ M501J 연소기 구성 : P-A,B/A/B/Tophat-stage



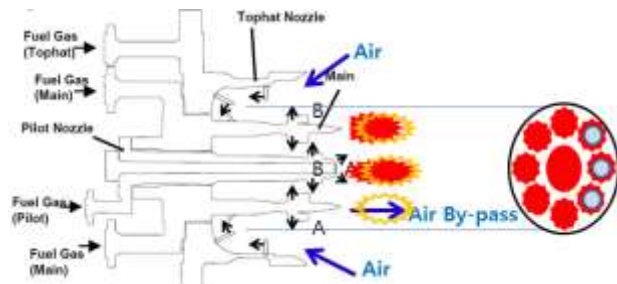
III.

실험대상(J)

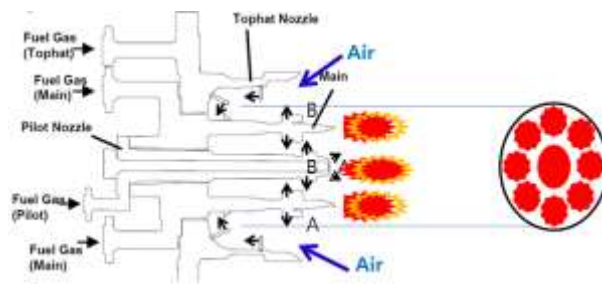
가스터빈 M501J DLN 연소기 운전



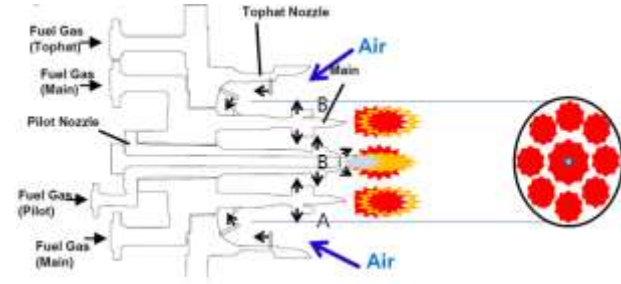
Pilot-A, Main-B(~full speed no load)



Pilot-A, Main-B, Tophat(~55MW)



Pilot-A, Main-A/B, Tophat(~100MW)

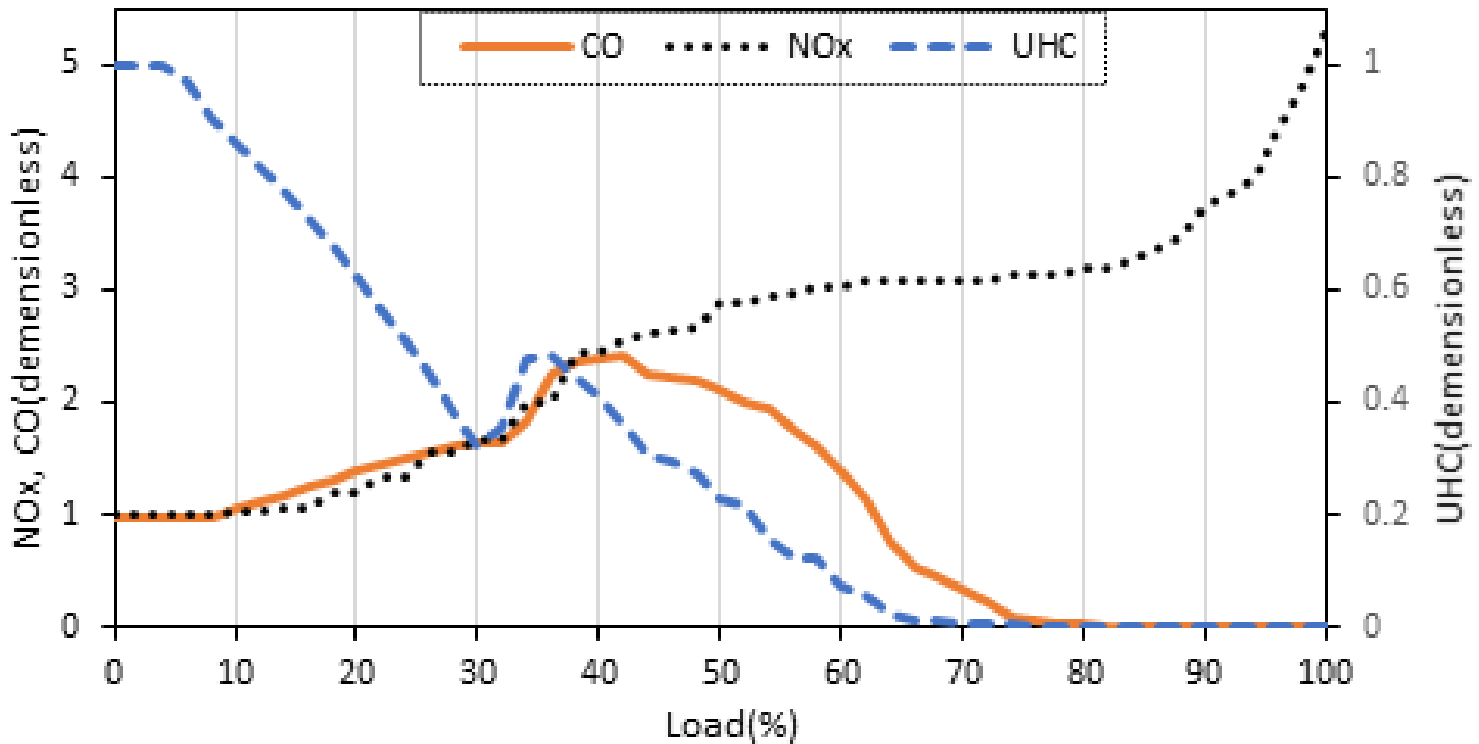


Pilot-B Operation(100~320MW)

IV.

실험결과(100MW급)

가스터빈(100MW급) DLN 연소기 운전

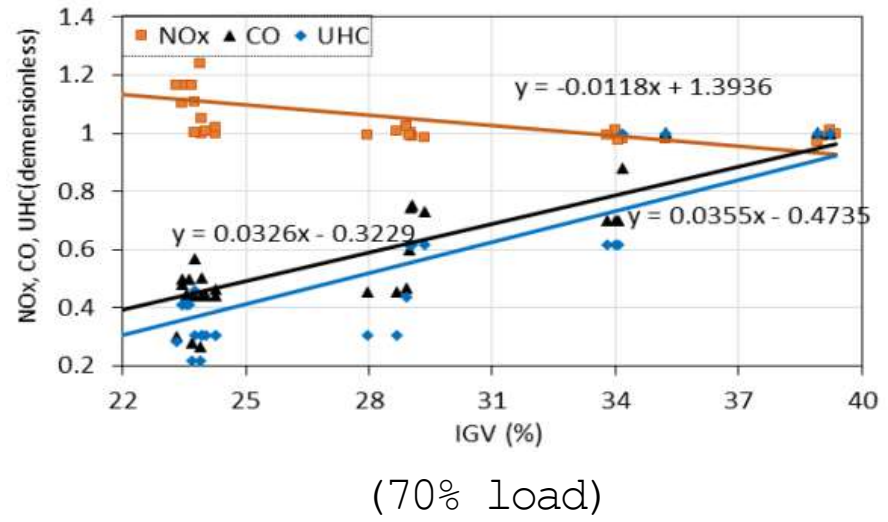
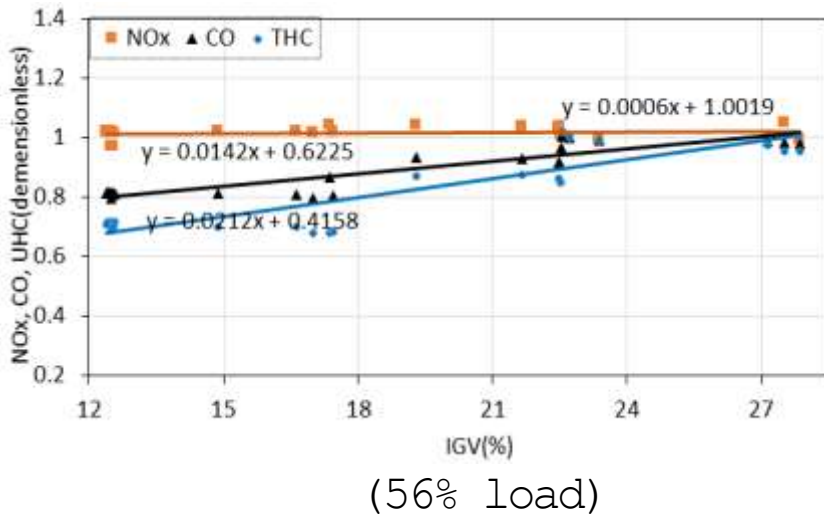
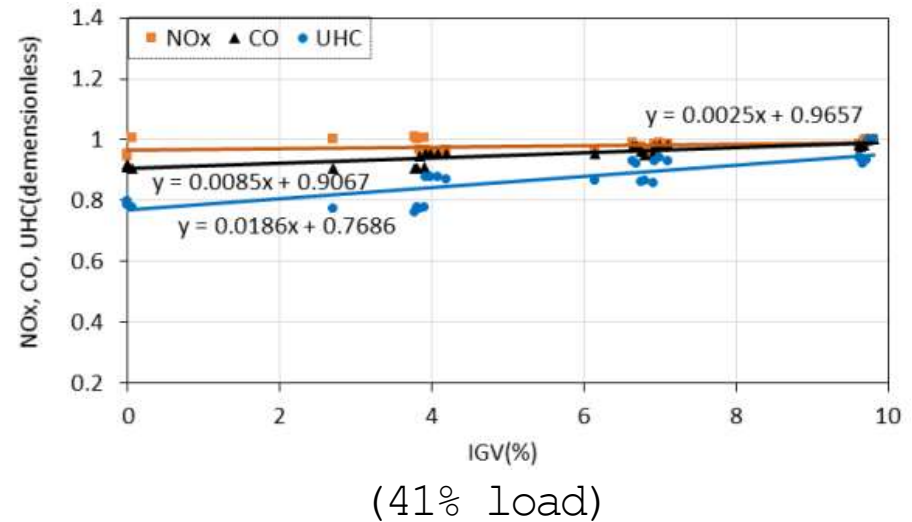
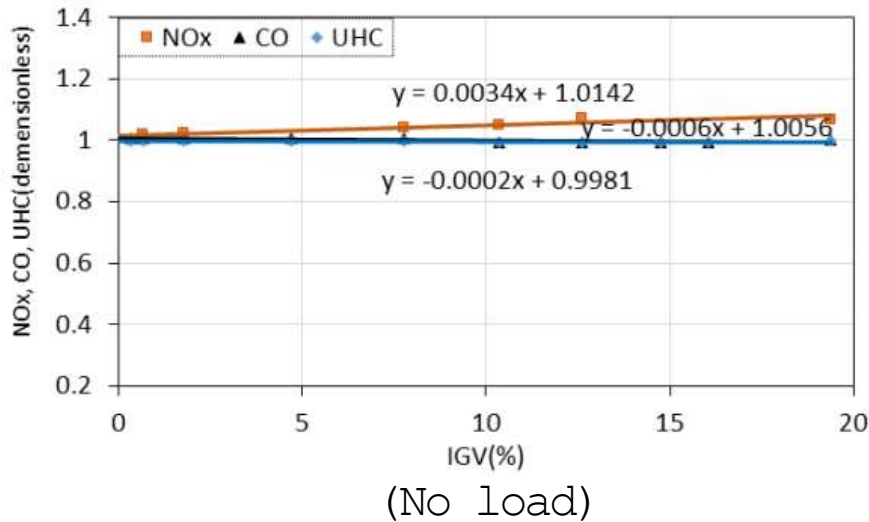


W501D5 가스터빈 (DLN-B) 의 출력별 배출물질 변화

IV.

실험결과(100MW급)

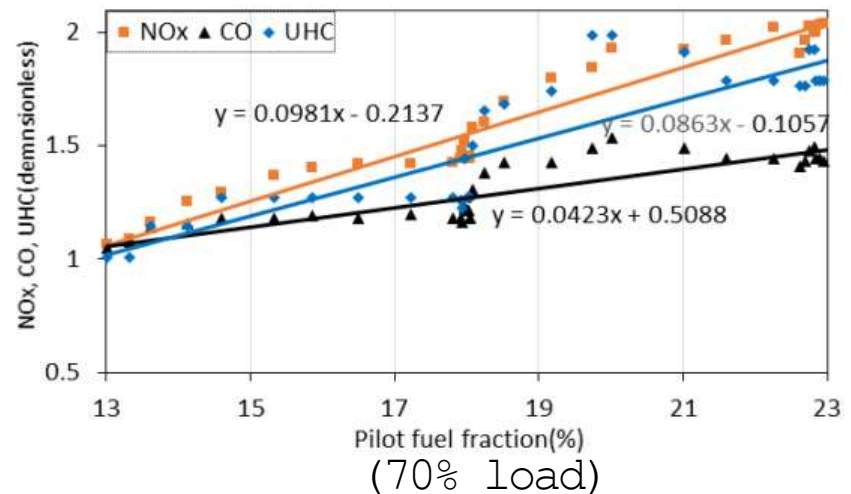
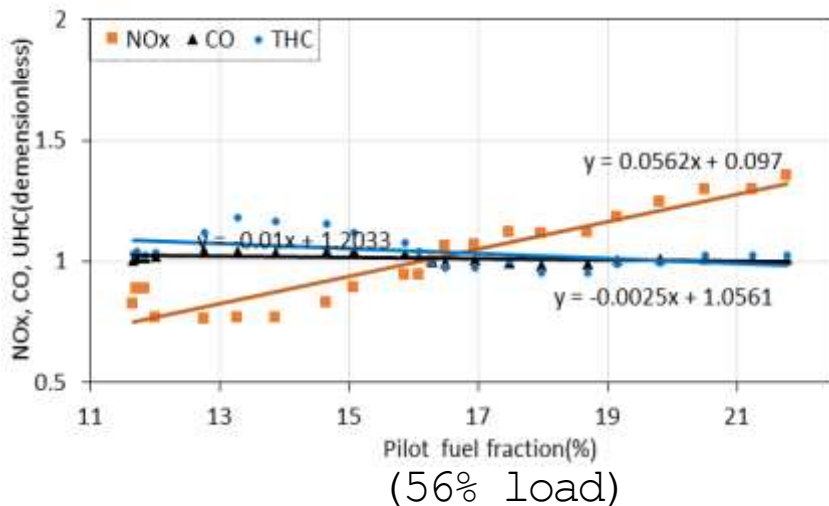
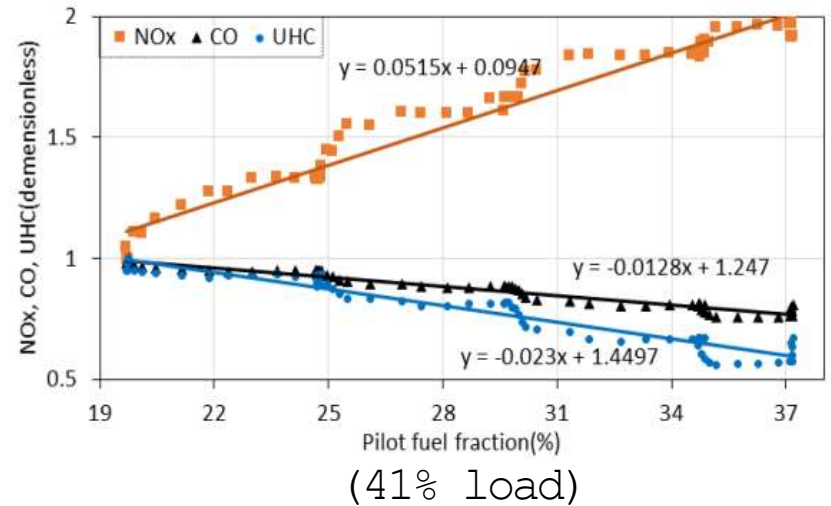
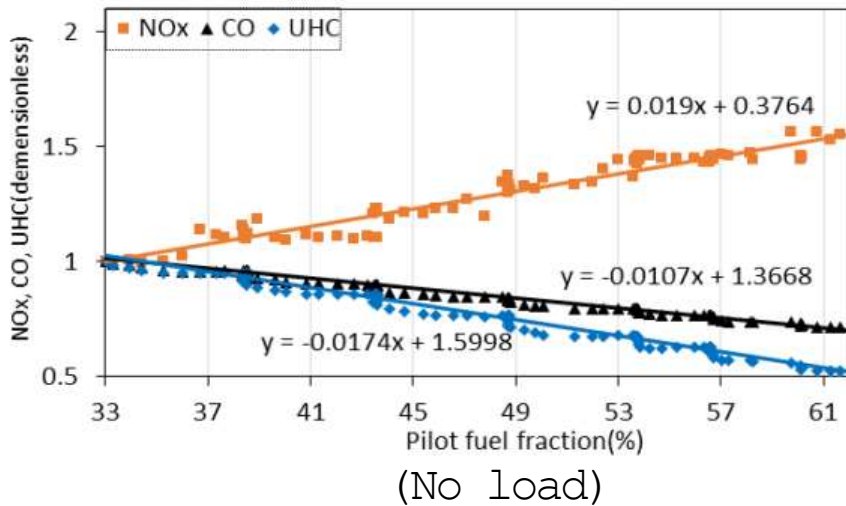
출력별 IGV개도(연소용 공기량) 변경 조건



IV.

실험결과(100MW급)

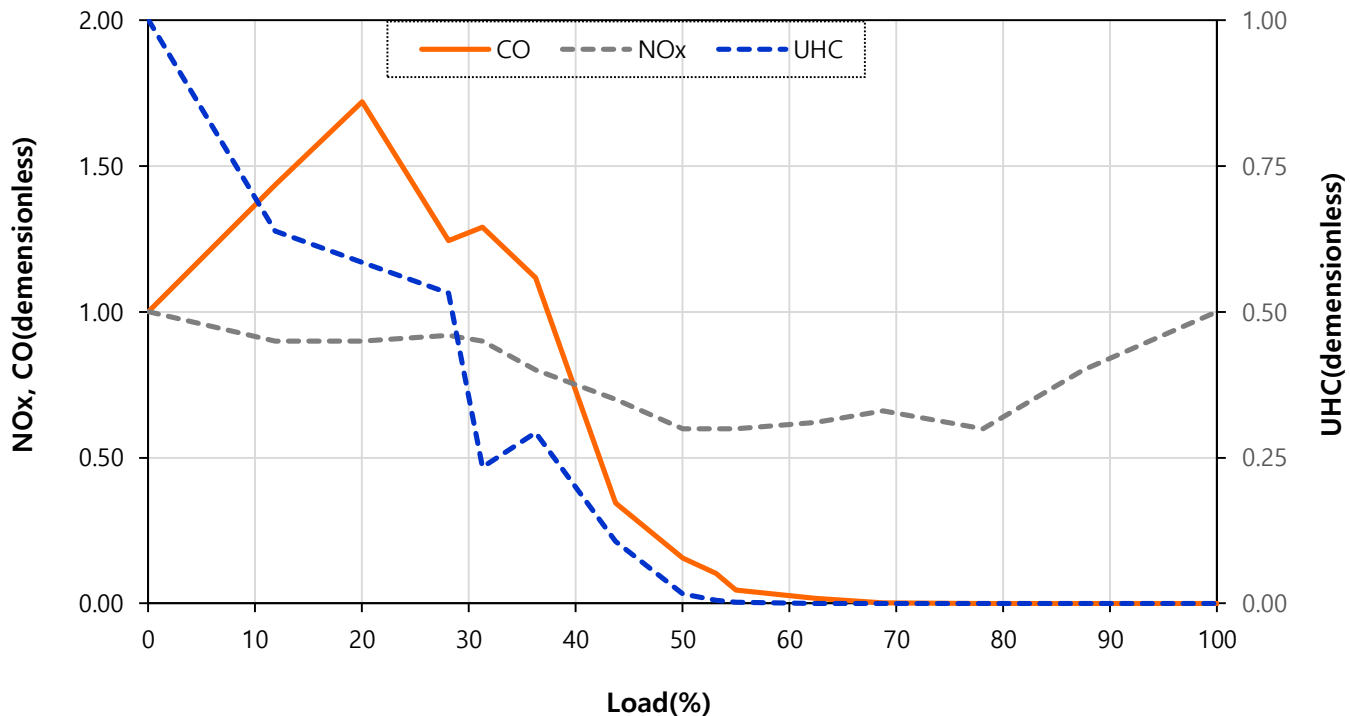
출력별 Pilot(확산화염) 연료비율 변경 조건



IV.

실험결과(160MW급)

가스터빈(160MW급) DLN 연소기 운전

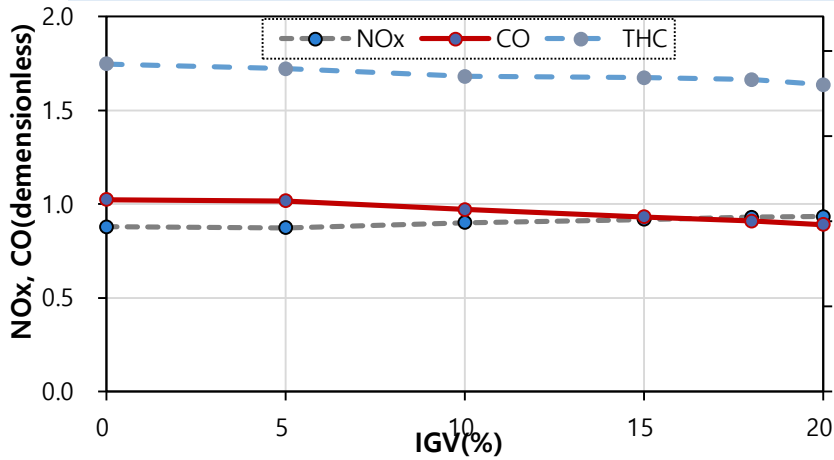


W501F 가스터빈 (DLN-B) 의 출력별 배출물질 변화

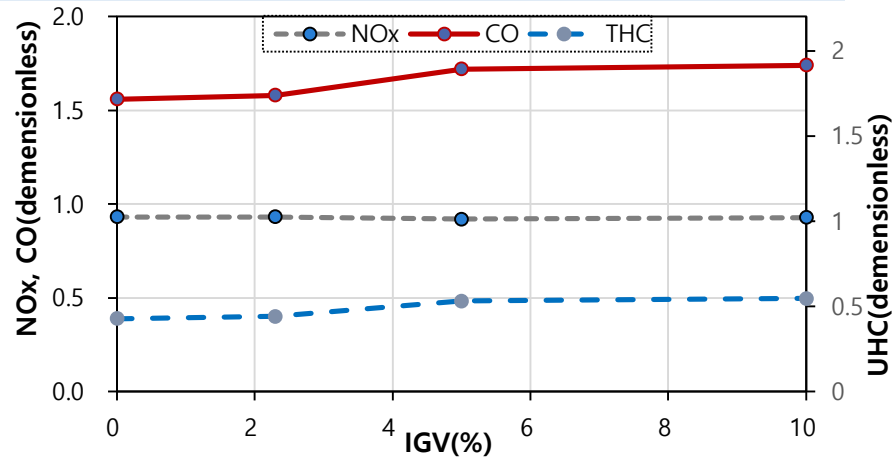
IV.

실험결과(160MW급)

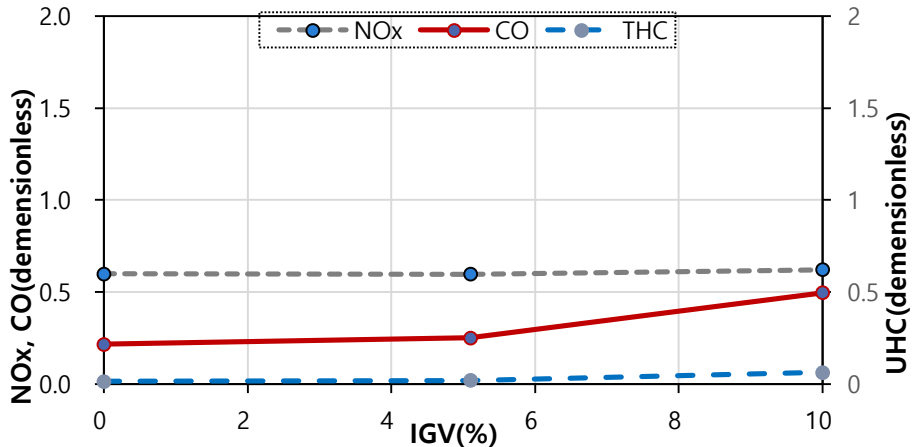
◎ 출력별 IGV개도(연소용 공기량) 변경 조건



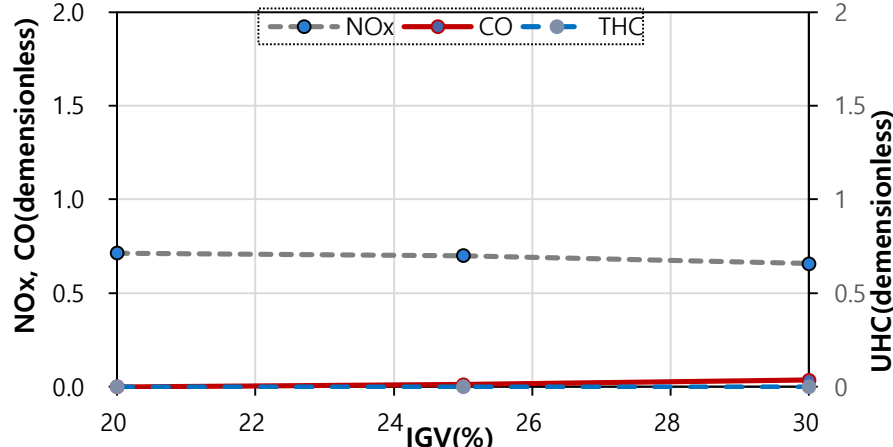
(No load)



(31% load)



(50% load)

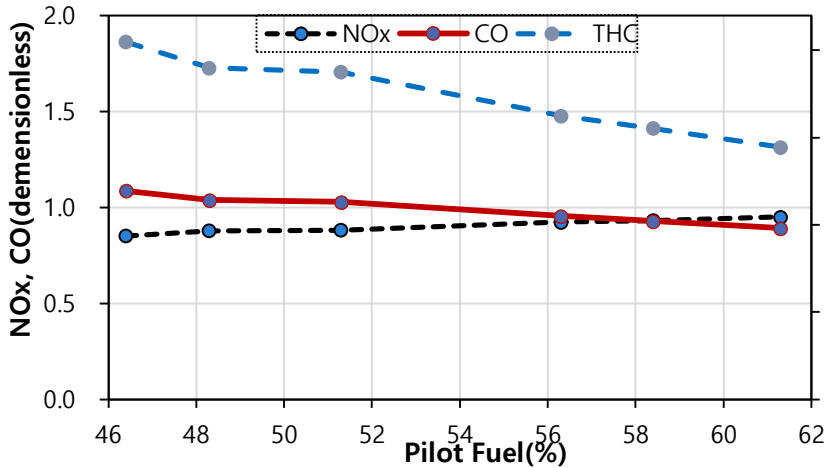


(70% load)

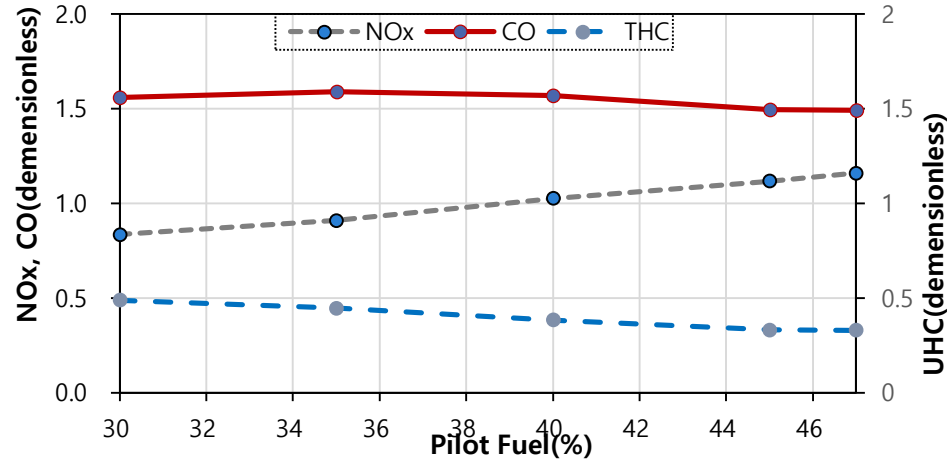
IV.

실험결과(160MW급)

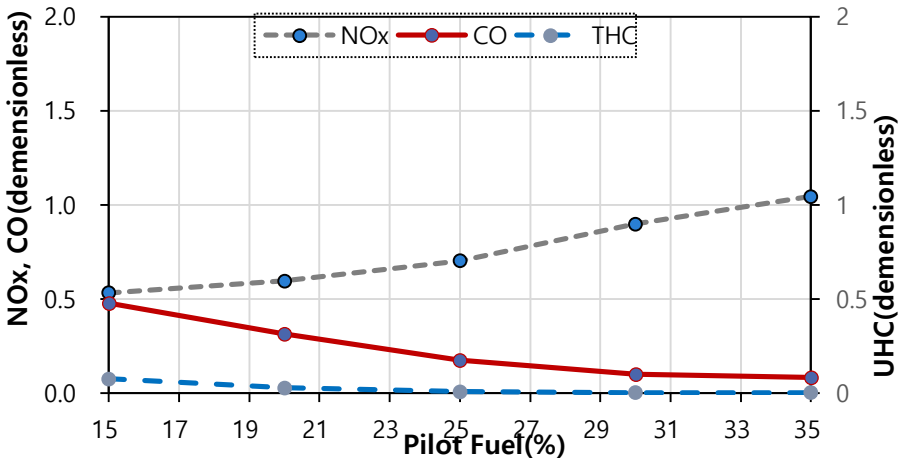
출력별 Pilot(확산화염) 연료비율 변경 조건



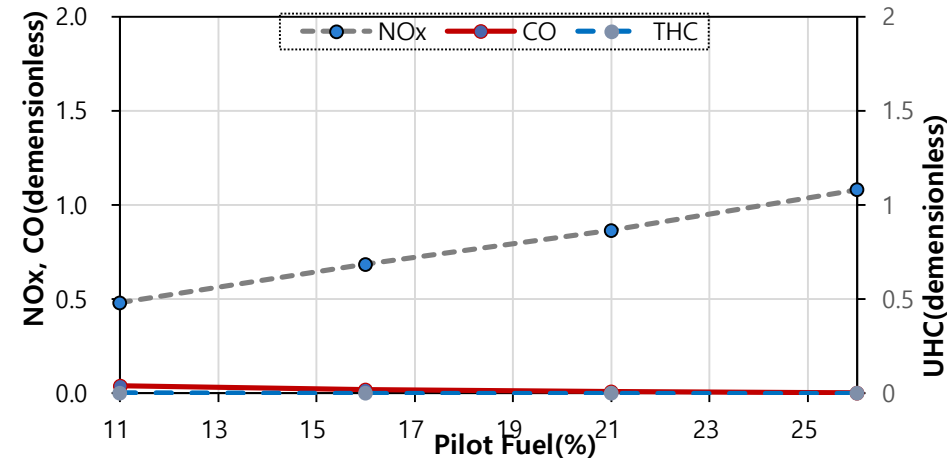
(No load)



(31% load)



(50% load)

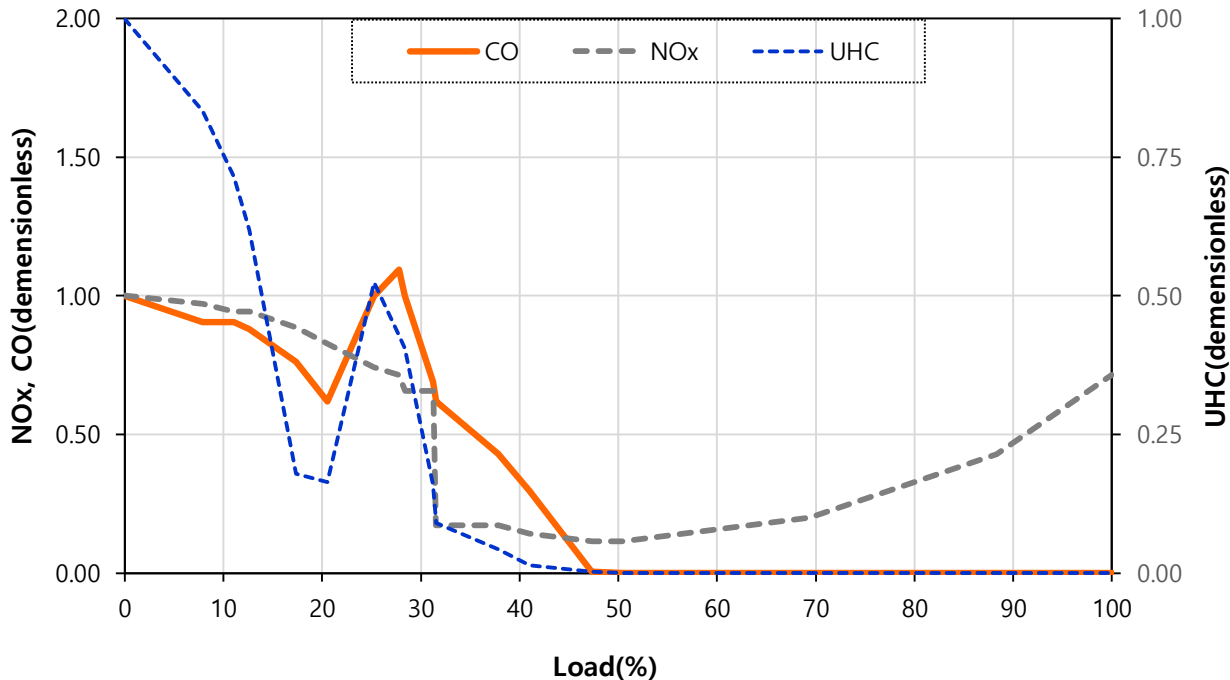


(70% load)

IV.

실험결과(320MW급)

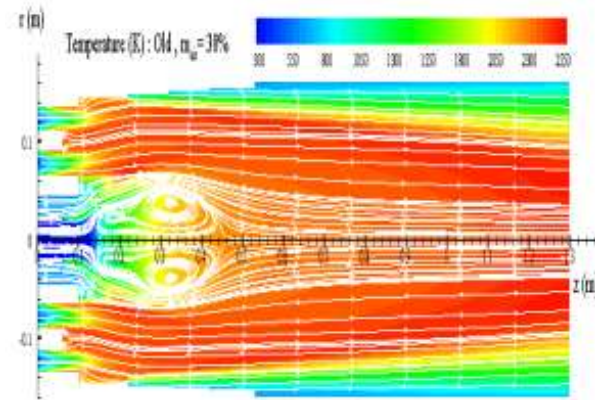
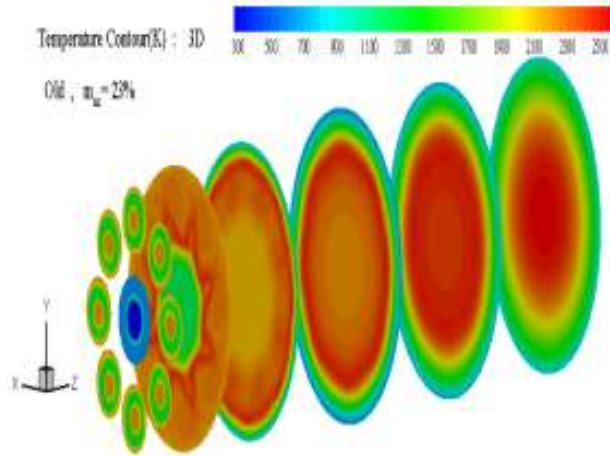
가스터빈(320MW급) DLN 연소기 운전



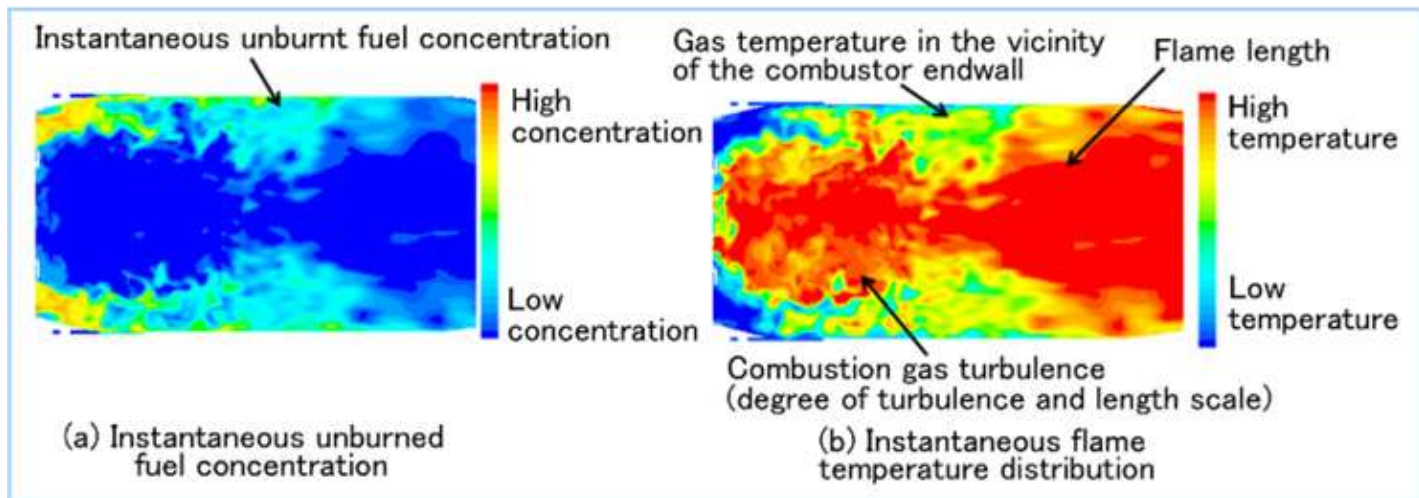
M501J 가스터빈 (DLN-B) 의 출력별 배출물질 변화

IV.

실험결과 고찰



[Temp. distribution with stream in 3-dimensional full combustor]

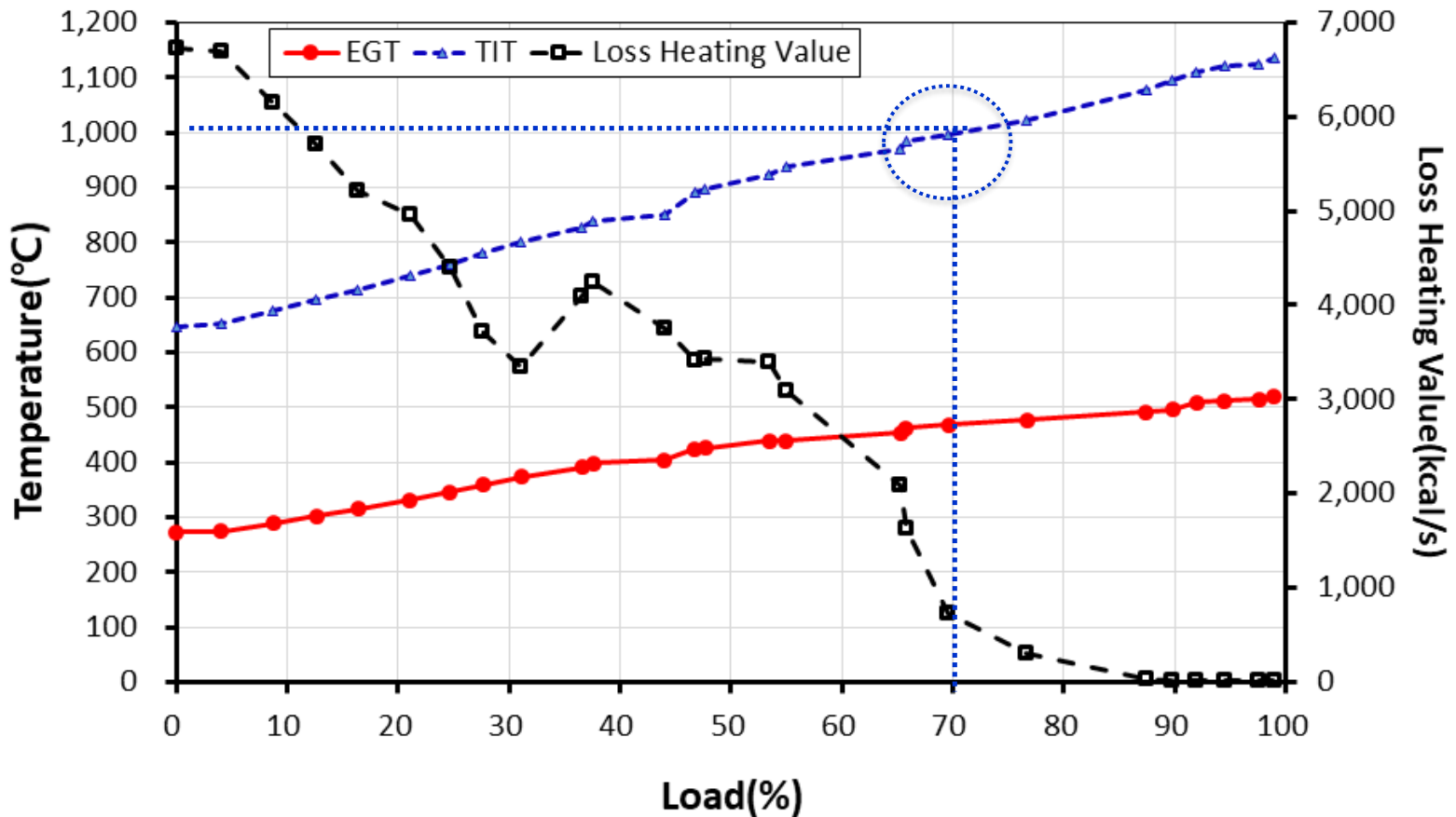


[Unburned fuel concentration and temperature in a gas turbine combustor *자료 : MHPS]

IV.

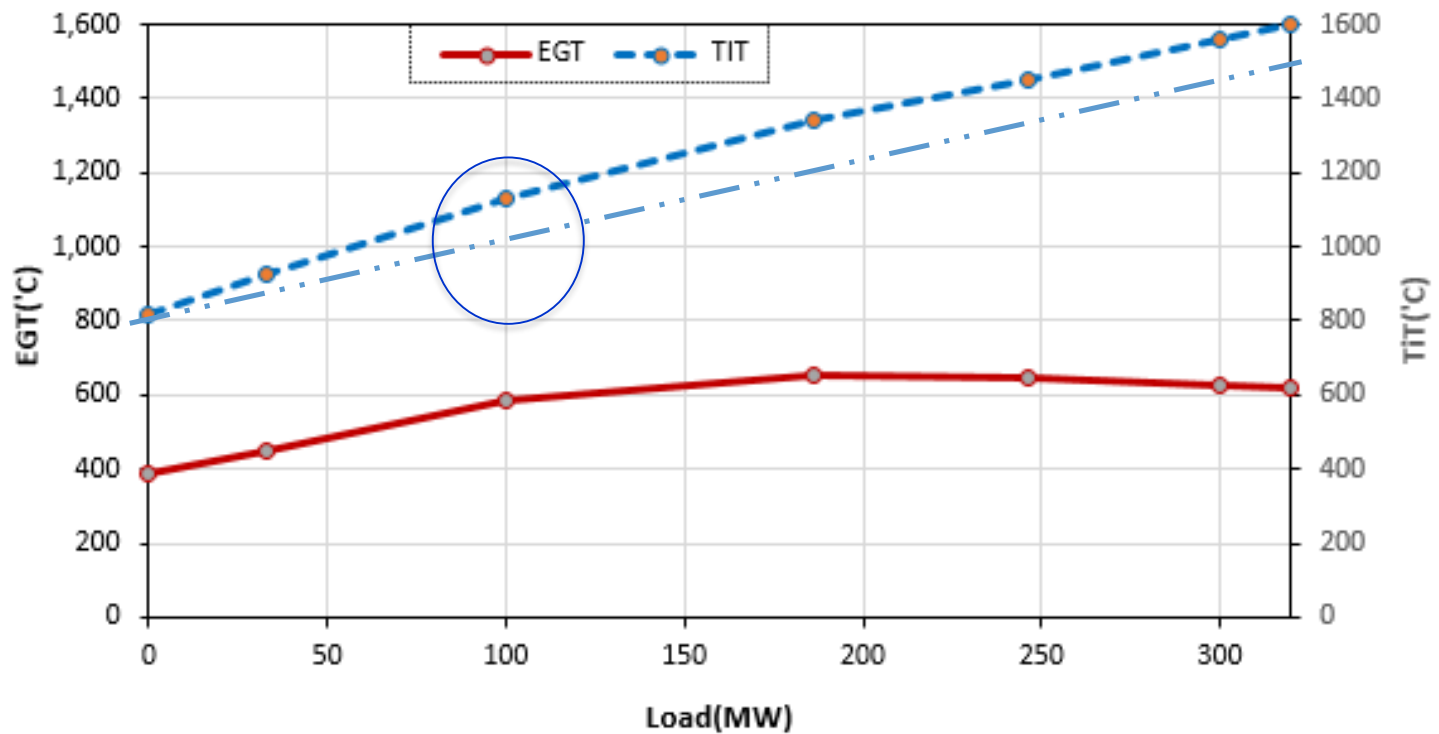
실험결과 고찰

◎ 100MW급 GT DLN 연소기 TIT 변화



[EGT, TIT and loss heating value by load of W501D5 GT]

◎ 320MW급 GT DLN 연소기 TIT 변화



320MW급 가스터빈 (DLN-B) 의 출력별 EGT, TIT 변화

- ◎ 1. 질소산화물 배출농도 변화
 - 확산화염 연료비율에 비례(기존 이론과 동일)
 - 연소공기량에 반비례, 고부하시 영향이 더 증가
 - ◎ 2. 미연탄화수소 배출농도 변화
 - 확산화염 연료비율과 저부하시 반비례, 고부하시 비례
 - 연소공기량과 비례, 고부하일수록 영향이 더 증가
 - ◎ 3. 일산화탄소 배출농도 변화
 - 미연탄화수소와 유사한 추세를 보임(동일 메커니즘)
 - UHC보다 늦게, 기동초기보다 중간부하에서 더 많이 발생
- UHC/CO₂ 배출저감을 위해서는 연소온도 저하영역 감소 필요
- 기동초기 저부하시는 Pilot 확산화염 연료비율 증가,
 - 부하가 증가할수록 연소용 공기량 감소가 효과적임
- * 연소영역 온도와 관련이 큼 - **TRIT 1000°C**이하 운전시간 최소화