CONSOLIDATED EDISON COMPANY OF NEW YORK

INDIAN POINT 2

BUCHANAN, NEW YORK, NY

QUALIFICATION SUMMARY REPORT

FOR

PASSIVE AUTOCATALYTIC RECOMBINER (PAR)

NOVEMBER 20, 1998

BACKGROUND AND CONCLUSION

In August of 1996, Consolidated Edison submitted an application (Reference 1) to change the Indian Point 2 combustible gas control system from the current "flame-type" recombiner to a Passive Autocatalytic Recombiner (PAR). Extensive developmental testing had been conducted for the PARs by both German sponsors and by the Electric Power Research Institute. Sandia National Laboratories under the sponsorship and direction of the NRC also performed performance tests of scaled PARs.

As a prerequisite for final installation at Indian Point 2, Consolidated Edison arranged for Equipment Qualification (EQ) testing at Wyle Laboratories in Huntsville Alabama. The Wyle test report (Reference 2) is available in Indian Point EQ files. This summary is based primarily on that report.

Samples from equipment device designed and built by NIS Ingenieurgesellschaft mbH (NIS) supplied for Indian Point 2 were subject to radiation and thermal aging, seismic simulation, and exposure to post-accident temperature, pressure and humidity. Functional performance was verified after successive steps.

There was no discernable impact on PAR integrity or function due to the radiation aging, thermal aging and seismic simulation.

Exposure to prototypic LOCA temperature and pressure and spray chemicals (2,000 ppm boron, buffered to a pH of 8, 24-hour spray on housing) caused the PAR to be initially slow to respond. However, the impact was temporary and functional acceptance criteria were met. Once started, functional performance was nominal.

A test anomaly was noted during three functional tests performed using test parameters beyond design basis. Two functional tests did not meet the acceptance criteria for startup. One test marginally met the criteria. In response to these three tests, NIS conducted examination and tests of the catalytic material. That examination, and an analysis of the conditions of the tests, led to the conclusion that several aspects of the initial testing adversely affected the catalytic reaction and were not representative of Indian Point accident conditions:

- Cartridges had been exposed to LOCA spray and chemicals outside the housing. This resulted in much higher deposition of chemicals than would be the case in Indian Point. Subsequent exposures sprayed a housing with cartridges inside and the tests were acceptable.

- Initial spray chemicals included buffering to a pH of 10. This resulted in a much higher loading of trisodium phosphate (TSP) than would be the case in Indian Point. Subsequent spray chemicals were buffered to a pH of 8 and the tests were successful

Based on the above results, Consolidated Edison is confident that the PARs will function as required during and following an accident such that containment hydrogen concentration would remain below 4%.

QUALIFICATION TESTING:

This is a summary report for Equipment Qualification (EQ) testing of Indian Point 2 PARs performed at Wyle Laboratories in Huntsville Alabama. All work on this qualification program was performed in accordance with Wyle Laboratories' Quality Assurance Program, which complies with the applicable requirements of ANSI/NCSL Z540-1, ISO 10012-1, Military Specification MIL-STD-45662A, 10CFR21, 10CFR50 Appendix B, ANSI N45.2, and the Regulatory Guides.

The qualification program included the following tests:

- Radiation Exposure
- Thermal Aging
- Seismic Simulation
- Post-Seismic Functional Test
- Accident Simulation
- Post-Accident Functional Test.

RADIATION EXPOSURE

Samples from equipment device designed and built by NIS supplied for Indian Point 2 were subject to radiation aging. The radiation exposure value exceeded the sum of normal plus accident plus margin.

THERMAL AGING

Same samples were subject to thermal aging. The purpose of the thermal aging is to put the cartridge specimens in their end-of-life condition prior to testing. The cartridges were thermal aged to simulate a 40-year equivalent life at 130 F for 100% of the time.

SEISMIC TESTING

The seismic testing was performed in accordance with IEEE Standard 344-1987, "IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations." A full-sized PAR with 88 cartridges including the irradiated and thermally aged sampled cartridges was installed on the Wyle Triaxial Seismic Simulator for seismic testing. The test PAR with 88 cartridges was subjected to triaxial multifrequency random motion. Three simultaneous, but independent, random signals were used as the excitation until the Test Response Spectra (TRS) enveloped the Required Response Spectra (RRS). The test PAR with 88 cartridges was subjected to five Operating Basis Earthquake (OBE) Tests and one Safe Shutdown Earthquake (SSE) Test. The horizontal and vertical RRS were based on the PAR location on the operating deck of the Indian Point 2 containment plus margin.

The TRS, RRS and Time History Plots are available in the EQ test report.

ACCIDENT SIMULATION TEST:

Five aged cartridges were placed in a LOCA test chamber. The cartridges were subjected to the Accident Temperature and Pressure Profiles. Chemical spray was started when the peak temperature of 287°F was obtained and then was continued for a 24-hour period. The chemical spray solution consisted of 2000 PPM boron (as boric acid) buffered with TSP to a pH of 10. The chemical spray flow rate that correlates to a chemical spray rate in IP-2 containment was used.

The accident simulation test was repeated for the additional five aged cartridges with the exception that the pH of the chemical spray solution was 8 (instead of 10) and the cartridges were housed in the 1/8-size PAR housing (instead of being totally exposed).

FUNCTIONAL TESTING:

Functional testing was performed on the irradiated, thermally-aged, and seismically tested cartridges installed in a 1/8-size PAR housing. The test was conducted inside an environmental chamber. The functional test was first performed after soaking the cartridges, then repeated without re-soaking the cartridges. The cartridges were soaked for approximately 30 minutes in a chemical spray solution consisting of 2000 PPM boron. The cartridges were soaked for an additional 30 minutes in a mixture of borated water buffered with TSP.

Nine functional tests (Tests A, B, C, D, E, F, G, H and I) were performed as shown in Table I and II. Three functional tests (E, F and G) were performed using test parameters beyond design basis. The various test combinations were as follows:

- Cartridges were subject to radiation thermal aging and seismic simulation. (Tests A, B, E, F, G, H and I)

- The cartridges were soaked for 30 minutes in a solution consisting of 2000 PPM boron. The cartridges were soaked for an additional 30 minutes in a mixture of borated water buffered with TSP to pH 10. (Tests A and C)

- The cartridges were soaked for 30 minutes in a chemical spray solution consisting of 2000 PPM boron. The cartridges were soaked

for an additional 30 minutes in a mixture of borated water buffered with TSP to pH 8. (Tests E, F and I)

- Aged cartridges were placed in a LOCA test chamber and were subjected to the Accident Temperature and Pressure Profiles. Also, sprayed directly with chemical solution consisted of 2000 PPM boron buffered with TSP to a pH of 10. (Tests E, F and G)

- Aged cartridges were placed in housing and the housing was placed in a LOCA test chamber. The chamber was subjected to the Accident Temperature and Pressure Profiles. Also, sprayed with chemical solution consisted of 2000 PPM boron buffered with TSP to a pH of 8. (Tests H and I).

- Five cartridges were mounted in the 1/8th size housing and the housing was mounted in the chamber. (All tests.)

- The chamber was sprayed with a buffered boric acid solution for about an hour. (Tests G, H)

- The chamber was refilled with a hydrogen-in-air mixture. The nominal refill concentration was 2% hydrogen.

- The chamber was sprayed with a buffered boric acid solution during the performance test. (Tests A, C, E, F and I)

- Hydrogen concentration, temperatures and chamber pressure were recorded.

ACCEPTANCE CRITERIA:

A functional acceptance criteria was specified based on the efficiency (about 10%) required for a single 88-plate PAR to maintain the Indian Point 2 containment below 4% hydrogen. A five-plate PAR with that reduced efficiency was calculated to reduce the hydrogen concentration in the test chamber by approximately 20% in two hours. Therefore, the acceptance criteria was:

> During the Functional Test, the hydrogen concentration shall be less than or equal to 75% of the peak concentration within two hours after the end of the hydrogen injection.

FUNCTIONAL TEST RESULTS:

- Test results for new and for aged (seismic, radiation and thermal) cartridges (Tests A, B, C and D) all reduced the hydrogen in the test chamber to less than 75% of the peak concentration within 20 minutes, well within the two hour acceptance criteria. All four results were quite similar and indicate that aging does not significantly affect PAR performance. See figure-1 for test results. Figure-1 shows normalized hydrogen concentration for tests A, B, C, and D as well as acceptance criteria.

- Results of functional tests E, F and G are discussed in test anomaly section.

- Test results (Tests H and I) for aged cartridges which had also been exposed to a design basis LOCA parameters met the two-hour acceptance criteria. However, catalyst heating in the first test (Test H) was very gradual for the first hour, effectively delaying the "startup" of the PAR by that amount. After the one-hour delay, hydrogen removal was essentially the same as the pre-LOCA tests (A, B, C & D). See figure-2 for test H and figure-3 for test I. Figure 2 and 3 shows normalized hydrogen concentration for test H and I respectively as well as the acceptance criteria.

  Hydrogen removal in the final test (Test I), while meeting the acceptance criteria by a wide margin, was slightly slower than in the pre-LOCA tests (A, B, C and D). Examination of the PAR-internal temperature traces shows a 10 or 12 minute plateau in the catalyst bed heat up which could account for the slower hydrogen removal. Such a plateau could indicate temporary cooling by water ingestion but heating was nominal after this temporary effect.

Within the context of the required performance at Indian Point 2, post-accident delays of a few hours are meaningless. Post-accident hydrogen concentration remains less than 4% for several days for a Design Basis Accident. Possible interference from containment spray is only expected for the first day or so since long-term containment cooling uses safety-grade coolers and not the containment spray. Those same coolers assure that containment humidity will be well below 100% thus enabling evaporation of any water inside the PAR long before hydrogen removal becomes necessary.

ANALYSIS OF TEST ANOMALIES:

Three post-accident functional tests (Tests E, F and G) were classified as "anomalies" in the EQ test report. Following these anomalies, Consolidated Edison sought to determine the cause of the anomalous behavior.

One of the five cartridges used in post-accident testing was shipped to NIS. They tested the cartridge in a single-plate test device.
Three tests were run in series:

- Test 1: Using 1% hydrogen in air as the test gas, there was very little evidence of catalytic heating.

- Test 2: Using a test gas with between 2% and 3.5% hydrogen in air, catalytic heating started immediately. The test was terminated when the internal temperatures reached about 100°C.

- Test 3: Again using 1% hydrogen in air, catalytic heating begins immediately.

The NIS conclusion from this test series was that the LOCA-exposed catalyst did have some sort of coating which was effective at inhibiting the reaction at 1% hydrogen but which did not remain effective at higher concentrations. It also appeared to be effectively removed by catalytic heating in the range of 100°C.

NIS further investigated this threshold inhibition phenomena using new samples of catalyst pellets. These pellets did not have the hydrophobic coating normally found on NIS PARs. NIS soaked the sample pellets for 24 hours in a boric acid/TSP solution similar to that used by EQ testing at Wyle. This sample was exposed for three hours to a flowing stream of 1.5% hydrogen in air and exhibited very low levels of catalytic heating. The heating increased somewhat when the gas concentration was increased to 2% for 30 minutes. When the concentration was increased to 2.5%, substantial heating was essentially immediate.

TABLE I

Functional Test Summary
Design Basis Tests (A, B, C, D, H and I)

Test No.	Title	Initial H2	H2 at 60 min.	Time for 75%	Testing Notes	Test Results	Comments
A	Post-Seismic Functional Test (wet/aged)	2.02	0.62	<19min	• soak(1hr); spray during test • chamber T=85F • PAR: 185/230/175F* peak	nominal	OK despite wetness and aging
B	Post-Seismic Functional Test (dry/aged)	2.16	0.69	<16min	• same cartridges as #A • chamber 81F • PAR: 228/288/248F peak	nominal	OK despite aging
C	Additional Functional Test	2.14	0.65	<12min	• new cartridges • soak(1hr); spray during test • chamber 78F • PAR: 192/210/130F peak	nominal	OK despite wetness
D	Additional Functional Test (dry/unaged)	2.13	0.69	<20min	• same cartridges as #C • chamber 73F • PAR: 234/255/195F peak	nominal	OK "as new"
H	Post-Accident Functional Test (dry/aged)	1.91	0.73 at 2 hrs	< 1hr, 20min	• new aged+LOCA cartridges • chamber 87F • PAR: 230/335/230F peak • reaction delayed 1 hour.	one hour delay, nominal after that.	OK despite aging and LOCA
I	Post-Accident Functional Test (wet/aged)	2.37	0.79	<24min	• same cartridges as #H • soak(1hr); spray during test • chamber 110F+ • PAR: 210/275/180F peak	nominal	OK despite wetness, aging, LOCA spray, and previous use.

TABLE II

Functional Test Summary
Beyond Design Basis Tests (E, F and G)

Test No.	Title	Initial H2	H2 at 60 min.	Time for 75%	Testing Notes	Test Results	Comments
E	Post-Accident Functional Test	2.22	1.99	test stopped	• soak(1hr); spray during test • chamber 83F • PAR: 86/86/87F peak • Test stopped at 2hrs (1.98% H2)	low level recombination	heavy loading from direct LOCA spray
F	Post-Accident Functional Test	2.21	1.6% at 33hrs	>48 hrs	• same cartridges as #E • soak(1hr); spray during test (0.5 hr) • chamber 57F • PAR: 85/82/83F peak • new 2% gas added at 4 hrs. • New 1% gas added at about 33, 52, & 62 hours	low level recombination	heavy loading from direct LOCA spray
G	Post-Accident Functional Test	1.12	0.951	~ 1hr, 20min	• same cartridges as #E & F • chamber 62F • PAR: 67/61/70F peak • Test stopped at 2 hrs • lowest H2=0.76% at 1hr, 50m, in top dome	low level recombination (marginally met acceptance criteria)	heavy loading from direct LOCA spray

* PAR temperatures are for thermocouples T4 (top frame), T5 (catalyst bed) and T6 (gas flow channel)

TABLE III

Cross-reference to EQ test report.

Test No.	Test Description	Reference to Wyle EQ test Report
A	Post-Seismic Functional Test (wet/aged)	Page XIII-5
B	Post-Seismic Functional Test (dry/aged)	Page XIII-17
C	Additional Functional Test (wet/unaged)	Page XIII-29
D	Additional Functional Test (dry/unaged)	Page XIII-41
E	Post-Accident Functional Test	Page I-10 and also page XIII-53
F	Post-Accident Functional Test	Page I-24 and also page XIII-69
G	Post-Accident Functional Test	page I-42 and also page XIII-89
H	Post-Accident Functional Test (dry/aged)	page XIII-103
I	Post-Accident Functional Test (wet/aged)	page XIII-119

References:

1) S. E. Quinn to Document Control Desk, USNRC, "Proposed Technical Specification for H2 Recombiners", August 21, 1996

2) "Nuclear Environmental Qualification Test Report on NIS Passive Autocatalytic Hydrogen Recombiners", Wyle Laboratories, Report 46189-1, Revision B, July 15, 1998

FIGURE 1

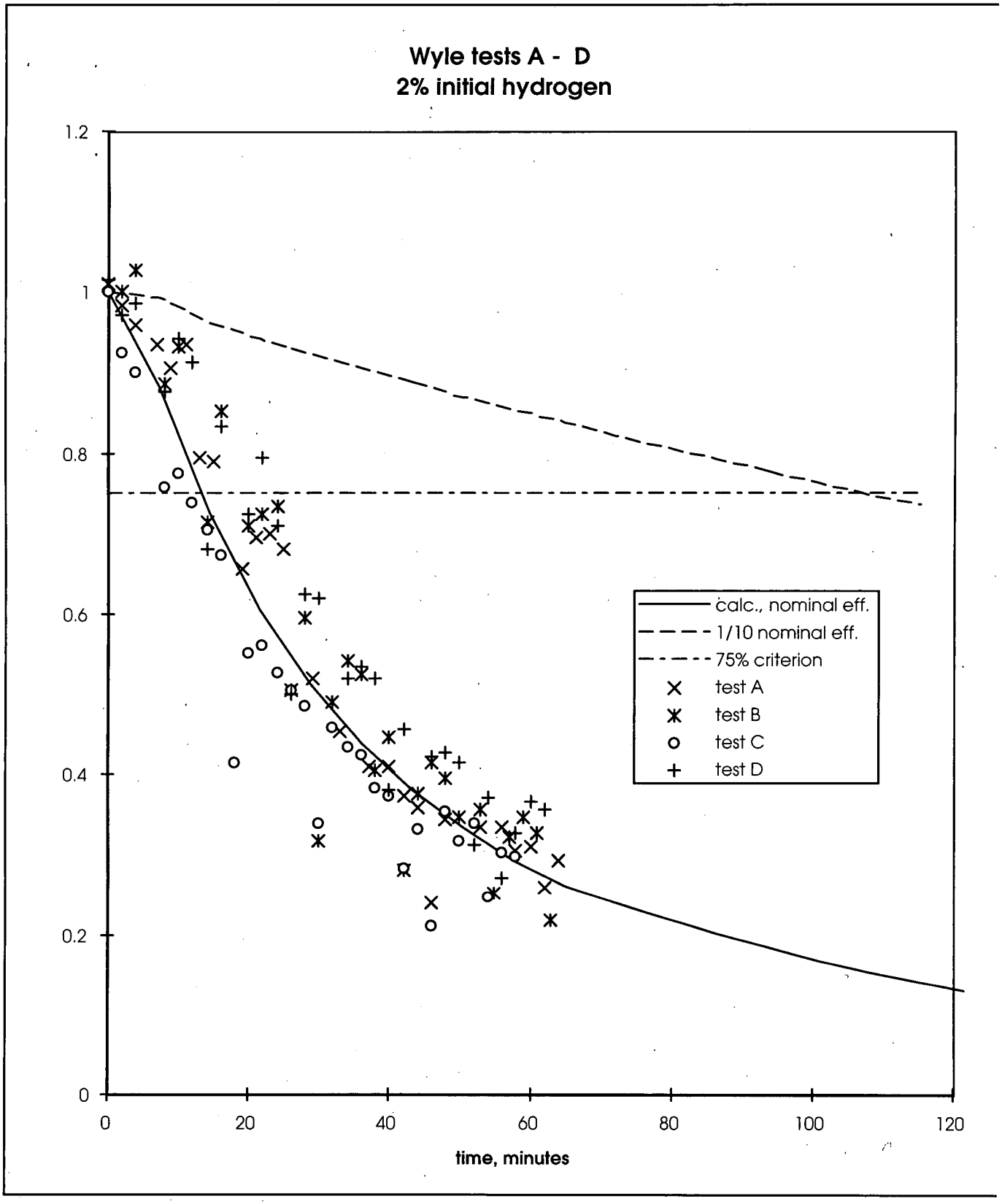

Wyle tests A - D
2% initial hydrogen
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
time, minutes
calc., nominal eff.
1/10 nominal eff.
75% criterion
test A
test B
test C
test D

FIGURE 2

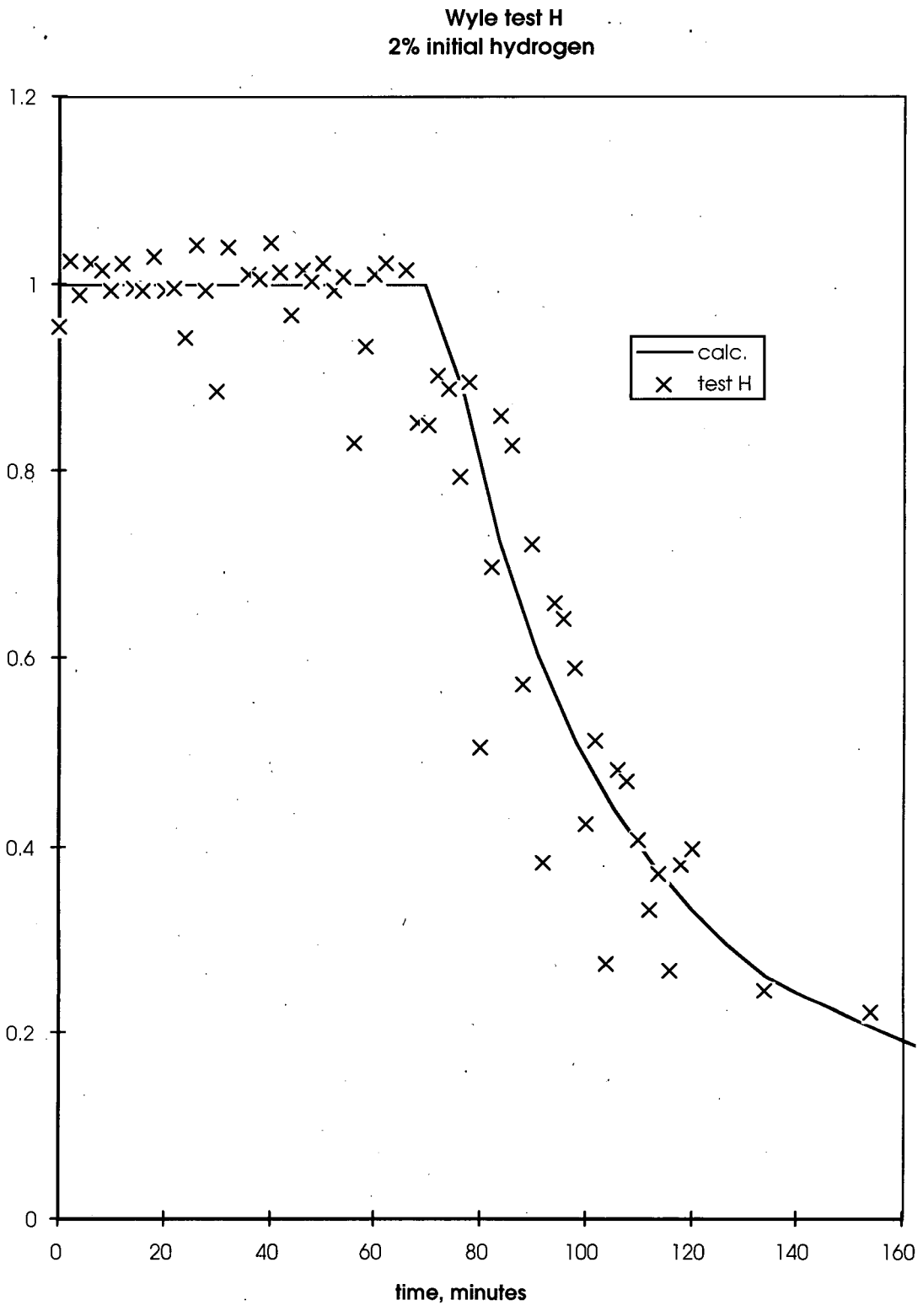
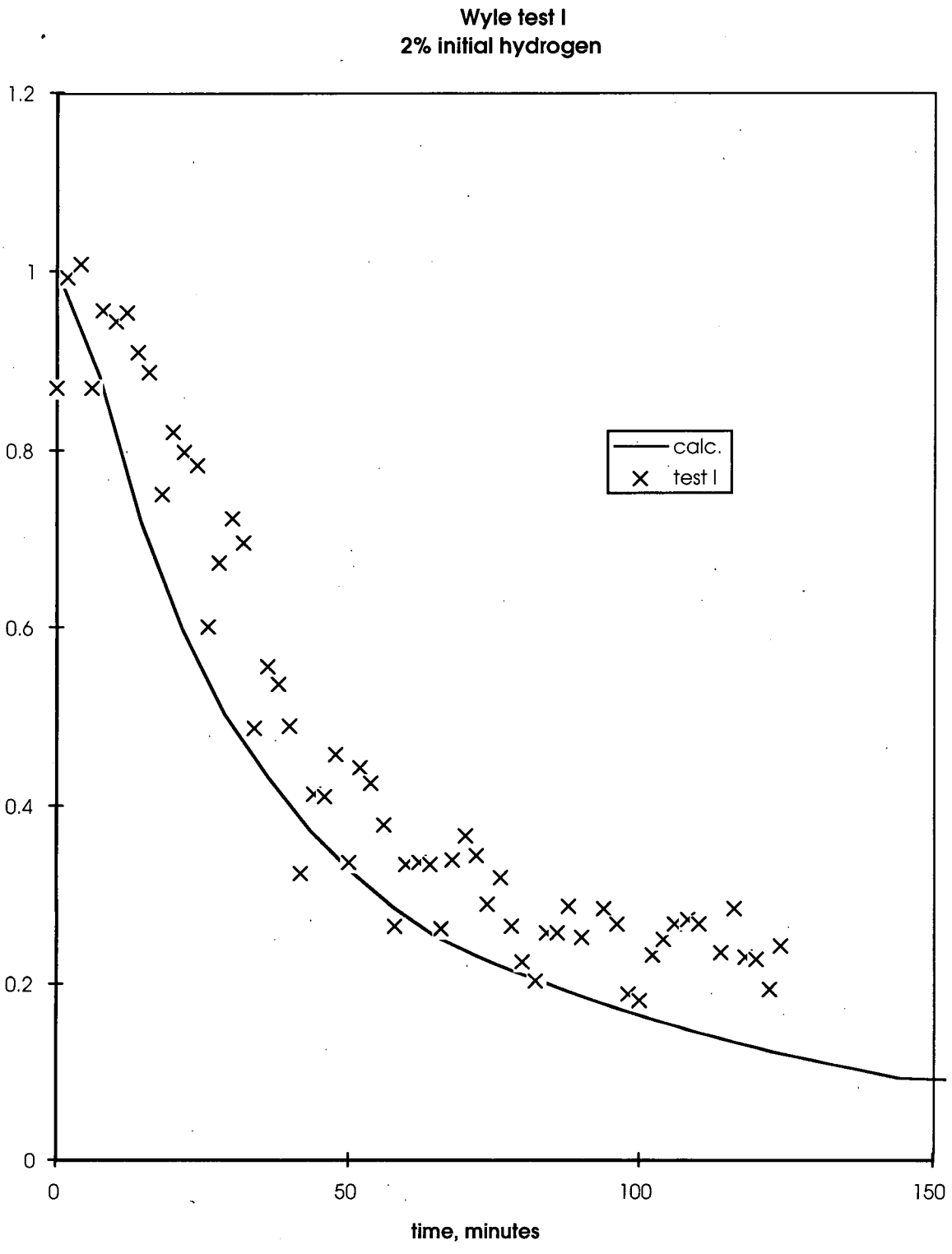

Wyle test H
2% initial hydrogen
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
140
160
time, minutes
calc.
test H

FIGURE 3


Wyle test I
2% initial hydrogen
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
calc.
test I
time, minutes