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READINESS THROUGH RESEARCH

DEMONSTRATION PLANT FOR PRESSURIZED GASIFICATION OF BIOMASS FEEDSTOCKS

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ABSTRACT

A project to design, construct, and operate a pressurized biomass gasification plant in Hawaii will begin in 1991. Negotiations are underway with the United States Department of Energy (DOE) which is co-funding the project with the state of Hawaii and industry. The gasifier is a scale-up of the pressurized fluidized-bed RENUGAS process developed by the Institute of Gas Technology (IGT). The project team consists of Pacific International Center for High Technology Research (PICHTR), Hawaii Natural Energy Institute (HNEI) of the University of Hawaii, Hawaiian Commercial and Sugar Company (HC&S), The Ralph M. Parsons Company, and IGT.

The gasifier will be designed for 70 tons per day of sugarcane fiber (bagasse) and will be located at the Paia factory of HC&S on the island of Maui. In addition to bagasse, other feedstocks such as wood, biomass wastes, and refuse-derived-fuel may be evaluated. The demonstration plant will ultimately supply part of the process energy needs for the sugar factory. The operation and testing phase will provide process information for both air- and oxygen-blown gasification, and at both low and high pressures. The process will be evaluated for both fuel gas and synthesis gas production, and for electrical power production with advanced power generation schemes.

DEMONSTRATION PLANT FOR PRESSURIZED GASIFICATION OF BIOMASS FEEDSTOCKS

INTRODUCTION

The Pacific International Center for High Technology Research (PICHTR) along with the Hawaii Natural Energy Institute (HNEI) of the University of Hawaii, the Hawaiian Commercial and Sugar Company (HC&S), The Ralph M. Parsons Company, and the Institute of Gas Technology (IGT) have been selected by the U.S. Department of Energy (DOE) in an open solicitation for a biomass gasifier scale-up facility project. The selection was made under DOE's Federal Assistance Solicitation for Cooperative Agreement Proposals (FASCAP) No. DE-PS02-89CH10407.

The purpose of the project, currently under contract negotiations with DOE, is to design, construct, and operate a pressurized biomass gasification demonstration plant in Hawaii beginning in 1991. The gasifier design is based on the pressurized oxygen-blown fluidized bed RENUGAS process developed by IGT as shown in Figure 1.

The demonstration gasification plant will be designed to gasify 70 tons per day of sugarcane fiber (bagasse) and will be located at the Paia sugar factory of HC&S on the island of Maui. The state of Hawaii is also co-funding the project. Other biomass feedstocks available in Hawaii will be tested in the gasifier. The main purpose of bagasse gasification will be to produce a synthesis gas for conversion to methanol since all fuels are imported to Hawaii. Another purpose of the demonstration plant will be to evaluate power generation options.

BACKGROUND OF HAWAII ENERGY FEEDSTOCKS

Hawaii, like most tropical islands, has no fossil fuels, and presently imports oil to supply approximately 90 percent of its energy needs. Biomass is the only renewable resource that can make Hawaii largely self-sufficient in energy in the near term. Hawaii has excellent conditions and extensive experience in the production of biomass and its conversion into useful forms of energy. The year-round growing season can produce 10 to 25 tons (dry basis) of biomass per acre per year. At such yields, sufficient fast-growing trees and grasses can be cultivated on less than 5 percent of Hawaii's land

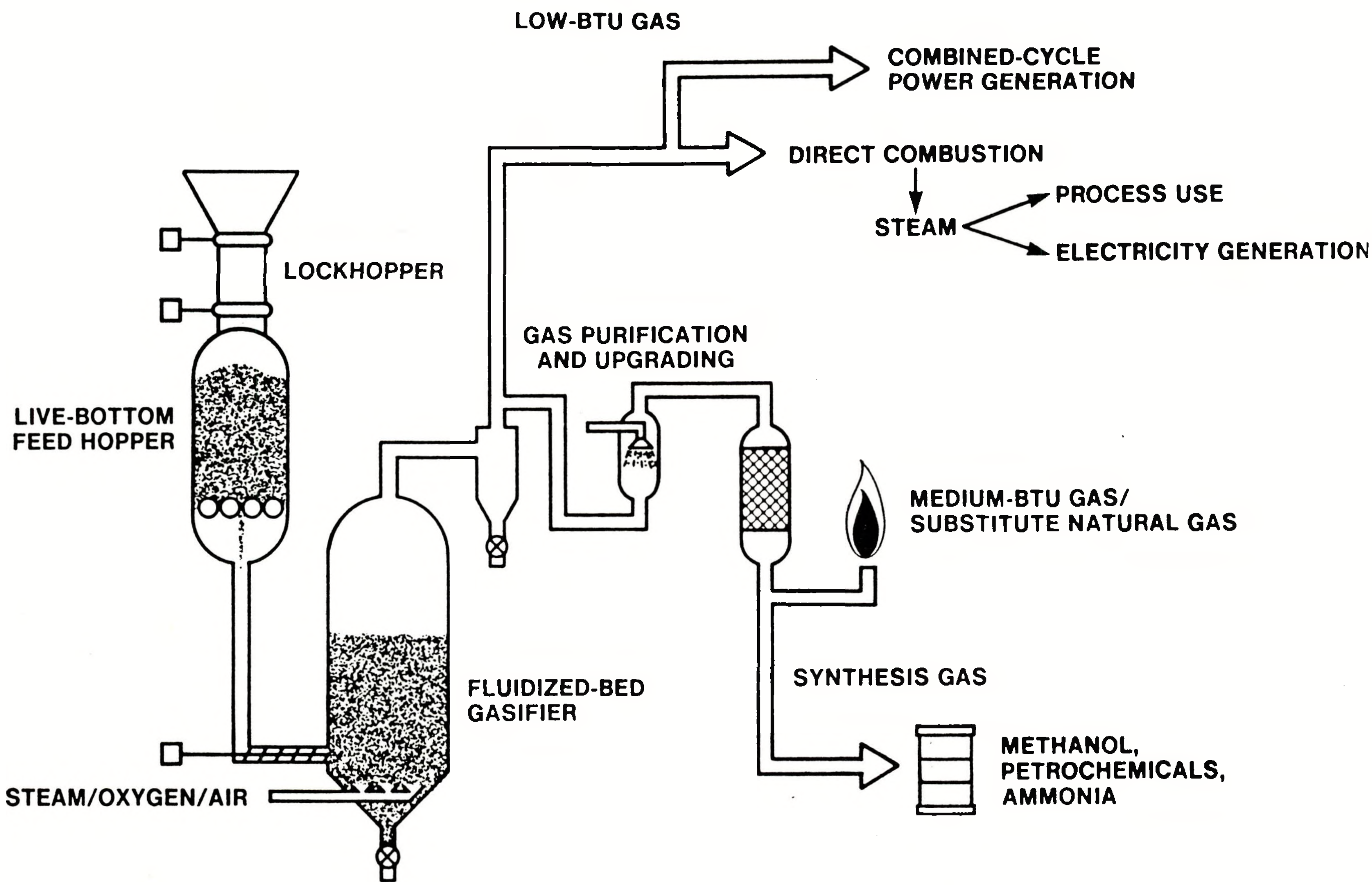

Figure 1. SIMPLIFIED PROCESS DIAGRAM OF RENUGAS SYSTEM

area to satisfy all of the state's requirement for ground transportation fuels.(1)

The primary feedstock to be used in the Hawaii gasifier demonstration program will be bagasse; some whole-tree-chips (mostly eucalyptus) will also be gasified to validate the performance observed in the RENUGAS process development unit (PDU), and other feedstocks such as refuse-derived-fuels (RDF) may be tested. Commitments to supply all three classes of feedstocks for the demonstration program have been secured from managers of a number of local biomass sources.

Bagasse has been the primary fuel of the Hawaiian sugar industry throughout its history. Bagasse was used prior to 1840 to fuel fires for sugar processing; by the mid 1800's, to generate steam to power mills; and, by the early 1900's, to produce electricity via steam turbine-generators.(2) Today, Hawaiian sugar factories annually produce about 800 million kWh, mostly from bagasse, and, after satisfying virtually all of their internal power requirements, export roughly 400 million kWh to public utility companies. Hawaiian sugarcane plantations produce roughly 10 percent of all electricity generated in the state, and in some counties up to one half of the electricity delivered to the general public by the utility companies originates from the sugar industry.

Processed wood has been used to varying degrees in Hawaiian sugar factory and utility power plants although its use has been much less extensive and more intermittent than bagasse primarily because of the lack of a large local lumber industry. Macadamia nut residues are also being used in Hawaiian macadamia processing plants to generate process steam and have occasionally been burned in sugar factory cogeneration facilities to supplement other fuels.

RDF has been used in a few sugar factory power plants, but only on a trial basis. In 1990, a privately operated RDF-fired electrical power generation plant, the Oahu Waste Energy Recovery Facility, was commissioned. This facility, one of only three of its type in the U.S., currently processes about 2000 tons of RDF daily and exports 60 MW to the local utility company.

DESCRIPTION OF RENUGAS PROCESS

The RENUGAS process was developed by IGT with support from the DOE. The process employs a single-stage pressurized, fluidized bed biomass gasifier able to handle a wide variety of biomass feedstocks. Either air-blown or oxygen-blown operation of the RENUGAS fluidized bed process is possible depending on the end-use for the product gas. Pressurized oxygen-blown gasification provides a gas which will improve the overall conversion process to methanol or higher alcohols. A pressurized product gas is advantageous to overcome pressure drops of downstream gas processing units, piping, and flow control stations, and is necessary for efficient combined cycle power generation schemes.

Renugas Process Development Unit

A 12 ton-per-day adiabatic process development unit (PDU) is operational at IGT and will be operated with the bagasse feedstock to obtain adiabatic process design information to minimize the technical risks of the demonstration plant design.(3,4) The IGT PDU is an 11.5-inch I.D. fluidized bed gasifier contained in an insulated 3-foot O.D. pressure vessel. The overall height of the vessel is 24 feet. Figure 2 shows an isometric view of the PDU equipment, with each deck 12 feet apart. Process heat for the PDU is supplied only by the introduction of air or oxygen. The PDU system was designed to operate at pressures up to 500 psig and at temperatures up to 1800°F. It is well instrumented to provide energy and material balances. It was also designed to be operationally flexible to test various feed point locations relative to the fluidized-bed height and the fluidizing gas distributor. A char recycle nozzle is installed on the PDU. Different test modules of various gas processing units can be installed at several convenient downstream locations for specific studies. Operational reliability of the RENUGAS gasification process has been demonstrated in many hours of testing in the PDU with different biomass feedstocks. Experience in feedstock handling characteristics has been gained by testing biomass feedstocks such as hardwood and whole-tree chips, highway brush clippings, pelletized refuse-derived fuel, paddy rice straw, and paper mill sludge and bark waste.(3,5,6) Typical PDU operating yields, efficiency, and gas quality data are presented in Table 1 for an oxygen-blown gasification Test No. T12-3a with whole-tree chips from

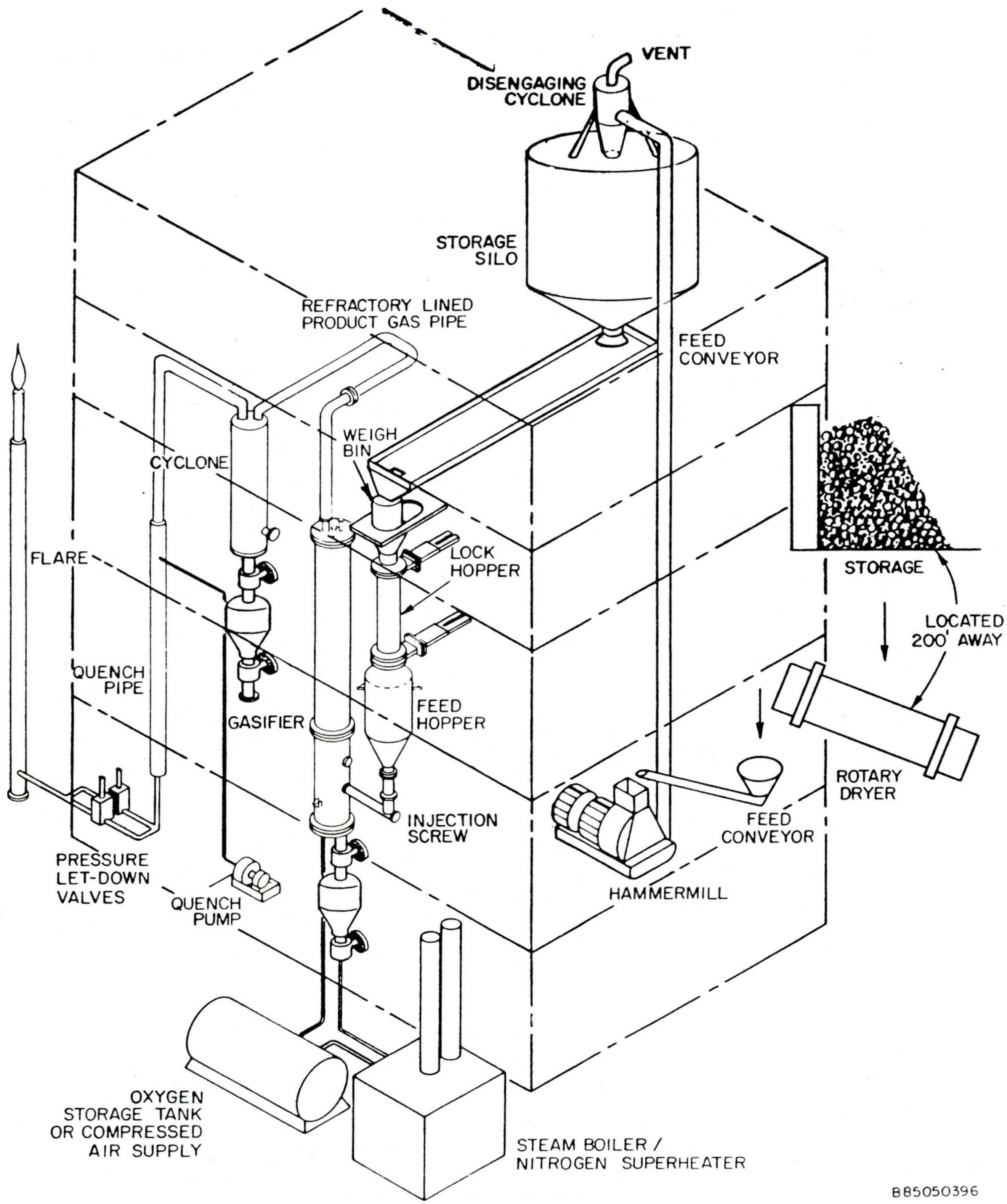

Figure 2. ISOMETRIC VIEW OF PDU EQUIPMENT

Table 1. SUMMARY OF ANALYZED RESULTS FOR RENUGAS TEST T12-3A (Test Date: 9/19/85, Data Analysis Period: 1100 to 1430 Hours)

Pressure, psia	317.70
Temperature, °F	1672
Feed Rate, lb/h (wet)	708.10
Moisture, wt %	9.14
Steam, lb/lb feed (wet)	0.69
Oxygen, lb/lb feed (wet)	0.26
Nitrogen, lb/lb feed (wet)	0.41
Product Gas Flow Rate, scf/h	27.472
Product Gas Composition, %	
H_2	12.69
CO	7.22
CO_2	17.42
CH_4	7.60
C_2H_4	0
C_2H_6	0.02
C_3H_8	0
C_6H_6	0.41
N_2	14.34
H_2O	40.30
Total	100.00
Molecular Weight	22.75
Dry, Inert Free Product Gas Composition, vol %	
H_2	27.98
CO	15.92
CO_2	38.40
CH_4	16.75
C_2H_2	0
C_2H_6	0.04
C_3H_8	0
C_6H_6	0.90
Total	100.00
Heating Value, Btu/scf	346.39
Dry, Inert Free Gas Yield, scf/lb feed (wet)	17.60
Cold Gas Thermal Efficiency, %	80.72
Superficial Gas Velocity, ft/s	2.01

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Wisconsin. The test was operated for 12 hours at steady-state beginning at 0700 hours with the material balance data gathered in the period from 1100 to 1430 hours. Similar information will be generated with bagasse in the PDU for the detailed demonstration plant design.

DESCRIPTION OF DEMONSTRATION PLANT

The demonstration plant will be designed to gasify 70 tons per day of bagasse based on test information to be obtained from the IGT PDU. The scaled-up gasifier will be about 4 feet I.D. with an overall height of about 30 feet. The bagasse will be fed by a feed system designed by Thomas R. Miles Consulting Design Engineers, of Portland, Oregon who have extensive experience in the design of pressurized biomass feed systems. The scale-up from the RENUGAS PDU to the demonstration plant is considered to be of low technical risk considering that scale-up factors are on the order of approximately 10.

A three-year program to design, construct, and operate the demonstration plant is planned. Figure 3 shows the area for the demonstration plant at the Paia factory site of HC&S. The gasifier fits well with the existing bagasse handling facilities. The gas produced by the demonstration plant will be burned along with bagasse in the existing boiler at the Paia factory during the test operation period. Increased boiler efficiency, reduced boiler maintenance, and lower fuel oil consumption are expected. Other test campaigns and process evaluations may be conducted on a product gas slip-stream from the demonstration plant to gain large-scale application information. Valuable process and equipment information will be gained about the constancy and reliability of long-term test operations.

Anticipated Demonstration Plant Tests

In the test campaigns anticipated for the demonstration plant, fuel gas, and synthesis gas applications will be evaluated. When the facility is fully operational, short-duration parametric evaluation tests lasting up to one day, will be followed by long-duration tests, lasting about 10 days. The parametric testing phase will develop a large-scale gasification data base that is necessary to evaluate alternative applications for pressurized gasification of biomass.

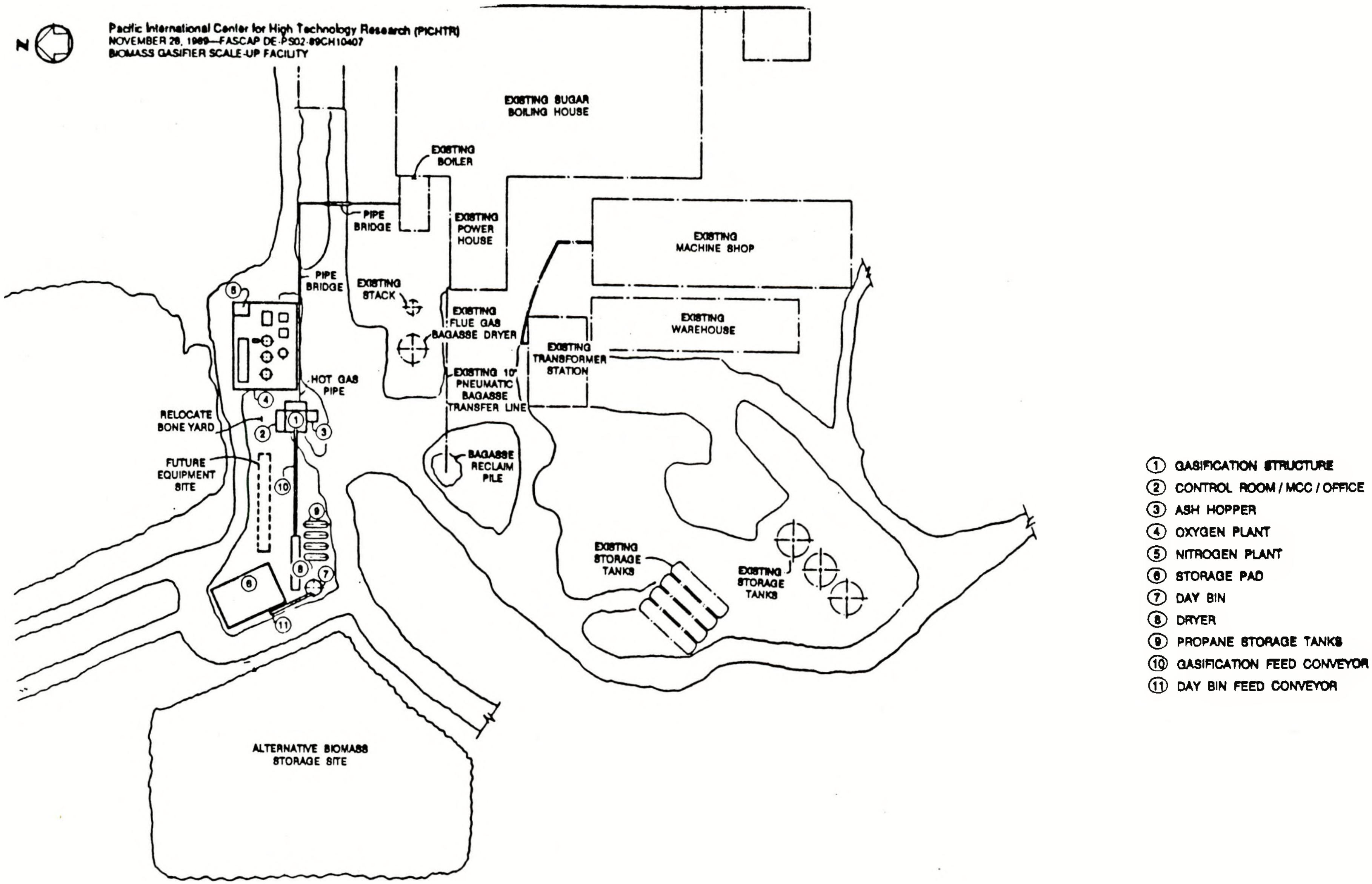

Figure 3. DEMONSTRATION PLANT PLAN FOR SUGAR FACTORY SITE

Key operating parameters include: 1) the gasification temperature, 2) operating pressure, 3) steam input, 4) type of feedstock, and 5) its moisture content and limiting feed rate. Bagasse, whole-tree chips, RDF, and other agricultural wastes will be candidate feedstocks in the test program.

The long-duration test conditions will be based on the parametric test data and will be conducted to demonstrate system reliability and to verify steady-state process performance. Also, in the long-duration tests the performance of the existing boiler fired on a combination of bagasse and fuel gas will be compared to direct burning of bagasse. Important design information will also include the ability of the gasification system to respond to and cope with variations in the type of feedstock, moisture content, and feed rate, to define the limits of the turndown ratio and gasifier banking.

Also anticipated in the test operations is the evaluation of add-on test modules on a product gas slip-stream for methanol synthesis, for hot gas cleanup systems, and for combined cycle power generation schemes. These investigations with actual gasification product gas at this scale would provide important data to support the development of various commercial options. The information from the demonstration plant tests will be used for scale-up to viable commercial plants and to develop preliminary capital and operating costs.

POTENTIAL OF BIOMASS GASIFICATION

The success of the RENUGAS process concept is embodied in the simplicity of a single-stage fluidized bed able to gasify a variety of biomass feedstocks. Simple process schemes with the highest thermal efficiencies have the best chance of commercial success. Favorable economics for biomass gasification are tied not just to fuel substitution issues in this era, but to waste disposal avoidance costs and environmental benefits of renewable fuels. The success of biomass gasification processes is also site-specific with good retrofit plant integration possibilities such as using waste heat to dry the biomass feedstock, using existing waste water treatment facilities, or eliminating the need for an electrostatic precipitator for fly ash control. Maximizing this integration with existing plants improves the overall thermal efficiencies and process economics over stand-alone plants.

Biomass gasification schemes have an added advantage in that a phased approach to construction and plant integration is practical considering that limited capital budgets of industry compete with projects that contribute directly to a corporation's production goals and competitive industry position. As an example of a phased installation, pressurized fuel gas could be first utilized in an existing boiler, then in the future with the benefit of operating experience, a combined cycle power generation system could be designed and installed.

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