

CLAIMS

1. A vacuum system, comprising:
at least one cryopump;
5 a plurality of sensors associated with said at least one cryopump each of
said plurality of sensors being configured to sense an operating condition of said
at least one cryopump;
diagnostic circuitry configured to receive signals sampled from at least
some of said plurality of sensors, said diagnostic circuitry comprising a diagnostic
10 model of said cryopump, said diagnostic model being derived from historical data
of a plurality of cryopumps of a same type operating over a plurality of
regeneration and servicing time periods and being configured to relate values of
said sampled signals from said at least some sensors to a probability of said
pump failing within a predetermined time, said diagnostic circuitry being
15 configured to apply said sampled signals to said diagnostic model and to
determine said probability of said at least one cryopump failing within said
predetermined time from an output of said model.
2. A vacuum system according to claim 1, wherein at least some of said
20 plurality of signals include at least some of: a first temperature of a first stage of
said cryopump, a second temperature of a second stage of said cryopump, a
time since a last regeneration, a speed of a motor of said cryopump, inputs to
heater circuitry, and a time for said cryopump to cool down to said first
temperature.
- 25 3. A vacuum system according to any preceding claim, said vacuum system
comprising a plurality of cryopumps, said diagnostic circuitry being configured to
receive signals from each of said plurality of cryopumps and to determine a
probability of each of said cryopumps failing.
- 30 4. A vacuum system according to any preceding claim, wherein said
diagnostic circuitry is responsive to detecting a probability of said at least one

cryopump failing being above a predetermined threshold value for a set time to output a warning indicating said pump should be replaced at a next scheduled preventive maintenance.

5 5. A vacuum system according to any preceding claim, said vacuum system comprising an input for receiving signals from a remote diagnostic system and an output for outputting signals to said remote diagnostic system.

6. A vacuum system according to claim 5, said vacuum system being
10 configured to periodically output data collected from at least some of said sensors along with data indicative of maintenance performed on said at least one cryopump to said remote diagnostic system.

7. A vacuum system according to claim 6, said vacuum system comprising
15 an input for receiving data from a service engineer indicative of a condition of a pump that is replaced during said maintenance period, said vacuum system being configured to output said data indicative of said condition of said replaced pump as part of said periodically output data.

20 8. A vacuum system according to any preceding claim, said vacuum system comprising an input configured to periodically receive updates to said diagnostic model.

9. A vacuum system according to claim 8, when dependent on any one of
25 claims 5 to 7, said vacuum system comprising an input configured to periodically receive said updates to said diagnostic model from said remote diagnostic system.

10. A method of monitoring a vacuum system, said vacuum system
30 comprising at least one cryopump, said method comprising:
 sampling a plurality of signals indicative of operating conditions of said at least one cryopump from sensors associated with said cryopump:

inputting at least some of said signals to a diagnostic model of said cryopump, said diagnostic model being derived from historical data of a plurality of cryopumps of a same type operating over a plurality of time periods, at least some of which include at least one of regeneration, servicing and failure of said pump, said diagnostic model relating signals to a probability of said pump failing;
5 determining from an output of said model a probability of said at least one cryopump failing.

11. A computer program comprising machine readable instructions, which
10 when executed by a computer are operable to control said computer to perform a method according to claim 10.

12. A method of generating a diagnostic model for a type of cryopump, said method comprising:
15 inputting into a machine learning algorithm data collected from sensing operating conditions of a plurality of cryopumps of said type from a database storing said sensed operating conditions of said plurality of cryopumps sampled over a plurality of time periods at least some of time periods including at least one of regeneration, servicing and failure, to generate a plurality of probabilities of
20 said pumps failing within a certain time;
comparing said probabilities for respective pumps with pump failure timings for said pumps retrieved from said database and updating parameters within said machine learning algorithm to reduce a difference between said determined probabilities and said pump failure timings; and
25 repeating said steps until said difference reaches one of a minimum or a predetermined value; and
generating said diagnostic model from said algorithm and parameters that provided said difference.

30 13. A method according to claim 12, wherein prior to inputting said data into said machine learning algorithm said signals are filtered to remove outlying data.

14. A method according to claim 12, or 13, wherein prior to inputting said received signals into said machine learning algorithm said signals are filtered to remove signals sampled a predetermined time before and after a regeneration of said cryopumps.

5

15. A method of updating said diagnostic model generated according to any one of claims 12 to 14, said method comprising:

receiving a plurality of signals indicative of operating conditions of a plurality of cryopumps of a same type;

10 receiving pump maintenance and failure timings for said plurality of cryopumps;

adding said received data to said database and performing said method of any one of claims 12 to 14 to generate an updated diagnostic model using data from said updated database; and

15 outputting said updated diagnostic model.

16. A method according to claim 15, further comprising receiving data indicative of a condition of a pump replaced following said diagnostic model indicating said pump would fail within a predetermined time, said data being input
20 to said machine learning algorithm during said updating of said diagnostic model

17. A computer program comprising machine readable instructions, which when executed by a computer is operable to control said computer to perform a method according to any one of claims 12 to 16.

25

18. A remote diagnostic module comprising a computer configured to execute said computer program according to claim 17.

19. A system comprising a vacuum system according to any one of claims 5 to 7 or 9, and said remote diagnostic module according to claim 18, said remote
30 diagnostic module being configured to receive signals output by said vacuum system and to update said database of cryopump operations with said received

signals and to generate an updated diagnostic model by inputting data from said updated data base to said machine learning algorithm.